

AN ABSTRACT OF THE THESIS OF

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Coopworth sheep, a newly available genotype, were compared with other genotypes in two trials to assess cumulative lamb and wool production and contributing components related to survival, reproduction and growth, and for the effects of ewe body weight on reproductive traits. In a third trial, various genotypes generated in the process of upgrading native Kaghani sheep, were evaluated for lamb and wool production. In the first two trials six ewe genotypes, generated by mating Coopworth (C), Polypay (P) and Suffolk (S) rams to Polypay and Coopworth-type ewes, were exposed to Hampshire rams for spring lambing from 1986 through 1990. Overall conception rate averaged 96% and ranged from 93% for S X C ewes to 97% for P X C ewes. Sire breeds were not different in ovulation rate but daughters of Polypay dams averaged .18 higher ovulation rate than daughters of Coopworth dams ( $P < .05$ ). Uterine efficiency for twin ovulators was .86 with little variation among sire breeds; however, daughters of Polypay ewes had a mean uterine efficiency of .93 compared to .78 for daughters of Coopworth ewes ( $P < .05$ ). Mean litter size at birth averaged 1.63 and ranged from 1.45 for C ewes to 1.75 for S X P ewes.

Ewes from Polypay dams had higher mean litter size ( $P < .01$ ) than those from Coopworth dams (1.73 vs 1.54), but differences between sire breeds were not significant. Ewes from Suffolk sires weaned the heaviest lambs while ewes from Polypay sires weaned the greatest number of lambs, resulting in similar weight of lamb weaned per ewe mated. Adjustment of lamb production for ewe metabolic body size resulted in Coopworth-sired ewes being more efficient than the heavier Suffolk-sired ewes. Coopworth-sired ewes produced 32% more wool than ewes sired by the other two breeds. Combining lamb and wool production in an index resulted in a range of less than 2% among sire breeds for gross productivity per ewe mated. Productivity of Rambouillet ewes studied under Pakistani conditions declined significantly over time. Crossbred lambs were generally heavier at weaning than Rambouillets, while wool production was highest in purebred Rambouillet ewes followed by genotypes related closely to Rambouillets. In all trials crossbreds generally excelled purebreds in overall productivity; the degree of superiority depended on genotypes involved in the crosses.

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# **GENETIC AND ENVIRONMENTAL VARIATION IN PRODUCTION COMPONENTS OF PUREBRED AND CROSSBRED EWES**

## **INTRODUCTION**

Increasing sheep productivity has long been a major concern for sheep producers. A number of research studies have indicated that improvement in overall sheep productivity can be achieved through systematic crossbreeding. Overall productivity of any species or genotype depends upon multiple components. Studies of genetic variation in productivity of livestock typically either are limited to a few of these components or measure gross production without reference to the relative contributions made by the various components. Likewise, studies of productivity are typically limited to measures of output without reference to variation in input parameters. In the case of meat production, output of the breeding population is dependent principally upon net reproductive rate (i.e. number) and size of progeny produced. Each of these, in turn, is dependent upon component parameters.

Productivity of Coopworths and Polypays, their reciprocal crosses, and crosses with Suffolk rams was measured to test the hypothesis that the newly imported Coopworth breed does not offer production advantages compared to locally available genotypes. Genotypes were evaluated by assessing contributing components related to survival, reproduction and growth. Relative efficiency of genotypes was assessed by adjusting gross lamb production for ewe body size, the best indicator of nutritional requirements as they apply to lamb production under grazing conditions.

Production of wool, the second product of dual purpose (lamb and wool) sheep, was also measured and related to lamb production.

Recognizing the importance of reproductive traits, genotypes were examined to determine ovulation rate, believed to be the primary factor limiting litter size. Genotypes were also compared for uterine efficiency to determine the importance of post-ovulation losses on litter size.

Lamb and wool production were also assessed in a Pakistani sheep population created by crossing imported Rambouillets with the local Kaghani breed.

## **LITERATURE REVIEW**

### **CHAPTER 1**

#### **INTRODUCTION**

Improvements in sheep production are necessary both for increased human needs and market competition. Assuming maintenance costs of breeding females increase less than the increased returns from their offspring, production efficiency can be improved by increasing total weight of lambs weaned per breeding female. Many component traits affect the composite (total weight of lambs weaned per ewe) performance of ewes. Among these are ovulation rate, conception rate, litter size, lamb survivability and lamb weaning weight. Wool production may be another important trait of ewes; its contribution towards total sheep productivity varies between breeds and countries.

Sheep breeds differ genetically in components of reproduction. These differences arise partly from selection for different objectives under different environments and partly from cumulative random change in gene frequency. Genetic differences among breeds are valuable assets which can be utilized in achieving new production goals arising from increased human needs and changing economics of sheep production. The challenge for the animal scientist is identifying and utilizing breed differences efficiently through the application of genetic principles.

There are two potential genetic approaches to achieve these goals. One is selection for component traits affecting overall performance; the

other is crossbreeding, which takes advantage of heterosis and is the basis of grading up and the development of new breeds. Comparison is made between benefits of selection vs crossbreeding techniques in the next section.

### MERITS OF SELECTION VS CROSSBREEDING

There are two main avenues for genetic improvement, selection and crossbreeding. Selection means the process of choosing superior animals as parents for the next generation within the same population, whereas crossbreeding is the mating of animals of different populations. Selection response is proportional to the heritability ( $h^2$ ) and selection differential (SD) and inversely proportional to the generation interval (GI) i.e  $\text{Response} = (h^2 \times \text{SD})/\text{GI}$

Heritability can be increased by basing selection on the average of more than one measurement of a trait; however, using repeat measurements of the same animals would increase generation interval and may offset the advantage of increased heritability. Increasing selection differential by selecting a smaller proportion of the population for replacements also leads to increased selection response if other factors remain constant. However, replacing a smaller proportion of the population generally increases generation interval which, in turn, decreases genetic improvement per year. Reducing generation interval will decrease selection differential because more replacements must be kept, resulting in a concomitant decrease in selection response. Therefore, effective selection programs have to balance all these factors in order to achieve as much genetic improvement per year as is practically possible.

Research endeavors have been made to improve sheep breeds in different parts of the world by selecting for growth and reproductive traits. Reproductive traits have low heritability (Turner, 1969; Clarke and Hohenboken, 1983) but, due to their high variability, significant

improvement in reproductive traits can be obtained (Turner, 1969; Clarke, 1972; Bradford, 1985). The real permanent long term gains come from selection for reproductive and growth traits in a given environment (Terrill, 1982).

On the other hand, crossbreeding of sheep gives quick gains in efficiency by combining desirable traits of different breeds. The advantages of crossbreeding are due to: 1) heterosis from systematic crossbreeding; 2) grading up to superior breeds; 3) development of new breeds (Dickerson, 1969); and 4) infusion of major genes such as the Booroola 'F' gene into other breeds (Bradford, 1985).

There are three types of heterosis (Nitter, 1978) which can be illustrated by assuming A, B and C are three sheep breeds:

1) Individual heterosis is defined as the improvement in performance of F1 reciprocal crossbred progeny relative to the mean of the purebred parents. It is not attributable to either maternal, paternal and sex-linkage effects.

$$\text{Individual heterosis} = [(A \times B) + (B \times A)]/2 - [(A \times A) + (B \times B)]/2$$

2) Maternal heterosis is defined as the improvement in performance of crossbred progeny by using crossbred instead of purebred dams. The improvement in progeny is due to increased milk production and improved uterine environment which reduces embryo mortality and consequently increases litter size. Maternal heterosis is estimated by:

$$\text{Maternal heterosis} = (C \times AB) - [(C \times A) + (C \times B)]/2$$

or if reciprocal ewes are available:

$$\text{Maternal heterosis} = [(C \times AB) + (C \times BA)]/2 - [(C \times A) + (C \times B)]/2$$

3) Paternal heterosis is defined as the superiority in performance due to

use of crossbred sires. It is typically exhibited through increased fertility and may be due to superior sexual drive.

Grading up is the process of repeatedly crossing sires of superior breeds to native breed females and their resulting female offspring. It can be used efficiently to convert a population of one breed into a population genetically identical to the breed of introduced sire. This technique is mostly used in the case of imported breeds where purebred males are available but purebred females are either not available or are available only in limited numbers. This approach was used in the USA where present Finnsheep were derived from grading up programs involving Finnsheep rams. During 1960-1970 grading up was also used to increase populations of several imported exotic cattle breeds in the USA. It is being widely practiced in developing countries to improve native sheep and cattle breeds.

Crossbreeding advantages can be obtained by development of a new synthetic breed through combining superior characteristics of several breeds. It may be very useful when no single existing breed adequately meets the needs of the production system. The synthetic breed will retain some proportion of hybrid vigor characteristic of the initial crossbred populations. Moreover, it may show higher response to selection than purebreds due to higher levels of genetic diversity. The Coopworth (New Zealand) and the Polypay (USA) are synthetic breeds developed by crossbreeding in the 1970's.

Crossbreeding also allows incorporation of major genes or specific characteristics from certain breeds. For instance, mean ovulation rate has been shown to increase by 1.0 to 1.5 ova for each copy of the Booroola



'F' gene (Piper et al., 1988). Davis (1983) also reported that lamb production increases by an average of one lamb for ewes carrying a copy of the Booroola 'F' gene. Likewise, crossing Romanov (Vesely and Swierstra, 1987) and Finnsheep (Dickerson and Laster, 1975) with US breeds results in earlier sexual maturity in the crossbred offspring.

## IMPROVEMENTS OF COMPONENTS OF OVERALL PRODUCTIVITY

A number of component traits such as ovulation rate, conception rate, litter size, survival of offspring to weaning and wool production affect the overall efficiency of breeding ewes. In this review an effort is made to look at reported responses in each component trait and the composite performance of ewes of different breeds and crosses when improved via selection or crossbreeding techniques.

### ***Ovulation Rate and Uterine Efficiency:***

Ovulation rate is a primary factor limiting litter size (Bradford, 1972). Average ovulation rate ranges from 1 to slightly over 2 for non-prolific sheep breeds. For prolific sheep breeds like the Finnsheep, Romanov and Booroola Merino, mean ovulation rate ranges from 3 to 4.

In recent years a major gene affecting ovulation rate and litter size has been reported in the Booroola Merino sheep (Piper and Bindon, 1982 a,b; Davis et al., 1982; Piper et al., 1985; Piper and Bindon 1987; Piper et al., 1988). Major genes have also been postulated in Javanese (Javanese Fat Tail and Javanese Thin Tail) sheep (Bradford et al., 1986) and the Cambridge breed (Hanrahan and Owen, 1985). In these breeds ovulation rate ranges from 1 to 15. Mean ovulation rates and litter sizes of several prolific breeds are presented below (Piper et al., 1988)

<u>Breed</u>	<u>Ovulation rate</u>		<u>Litter size</u>	
	<u>Mean</u>	<u>Range</u>	<u>Mean</u>	<u>Range</u>
Finnsheep	3.5	1-9	2.6	1-7
Romanov	3.4	1-7	2.6	1-5
Booroola Merino	4.2	1-15	2.5	1-7
Cambridge	4.2	1-13	3.1	1-8
Javanese	2.0	1-5	1.8	1-5
D'Man	2.8	1-8	2.1	1-6

Most studies describing the effect of a major gene on prolificacy have been conducted in Booroola Merinos. The major gene responsible for high prolificacy in Booroola Merinos has been named the 'F' gene. It follows the laws of Mendelian inheritance in segregation. The effect of the 'F' gene appears to be additive for ovulation rate and partially dominant for litter size (Davis et al., 1982). Each copy of the 'F' gene increases average ovulation rate by 1 to 1.5 (Piper et al., 1988). The first copy of the 'F' gene results in an average increase of 1 lamb over the average litter size of the non-prolific breed into which it is introduced. The additional effect of a second copy of the 'F' gene to increase litter size is dependent on other genetic and/or non genetic factors. The most important of the genetic factors is uterine capability to support multiple lambs following conception to multiple ovulations. Meyer (1985) introduced the concept of 'uterine efficiency', defining it as the marginal response in litter size resulting from one additional egg ovulated, i.e. measuring it in ewes conceiving to multiple ovulations. The typical decrease in uterine efficiency observed with increasing

ovulation rate may explain the phenomenon of dominance of the 'F' gene in determining litter size.

Davis et al. (1987) examined mature ewes of highly prolific flocks of Romney, Coopworth and Perendale sheep and observed mean ovulation rates of 2.27, 2.13 and 2.07, respectively. Mean litter sizes were 1.94, 1.88 and 1.78, ranking in the same order as mean ovulation rates. These high flock levels were achieved by screening large numbers of ewes to create the prolific flocks.

Studies of sheep flocks selected for litter size for 16-20 years provide evidence of increased ovulation rate as the basis for responses in litter size. In 1948, Wallace initiated a selection experiment for litter size at Ruakura research center in New Zealand. He formed three closed lines, each of 100 mixed age ewes, by selecting sheep from a recorded flock of 1000 Romney ewes (Wallace, 1964). This flock has become known as the Ruakura fertility flock (Clarke, 1972). Its three lines have been maintained as separate self-contained breeding units of similar age composition, but managed together as a single flock. From the base population, animals were selected for increased litter size (High line), decreased litter size (Low line) or at random (Control line). As a result of long term selection, litter size for 2 to 4 year old ewes from 1967 through 1970 in High, Low and Control lines averaged 1.62, 1.13, 1.22, respectively, (Clarke, 1972). Meyer and Clarke (1982) found substantial difference in ovulation rates among the lines with mean ovulation rates of High, Low and Control ewes being 1.96, 1.22 and 1.47, respectively. Ovulation rate in the high line was 33% higher than for the control line.

Quirke et al. (1985) reported ovulation rates of 5 lines selected

from the same base population of Targhee sheep. Among these were two control (C) lines, two lines selected for 21 years for increased 120 day weight (W), and one line selected for 19 years for multiple births (T line). Synchronized yearling ewes exhibited mean ovulation rates over the first two estrus cycles of 1.23, 1.38 and 1.44 for C,W and T lines, respectively. The corresponding values for mature ewes were 1.37, 1.55 and 1.58. Ovulation rates in the lines selected for litter size were 17 and 15% higher in yearling and mature ewes, respectively, than the control line.

Heritability estimates of ovulation rate are generally higher than heritability estimates of litter size, although a great deal of variation exists among reported heritability estimates. For instance, heritability estimates reported for ovulation rate have included .16 in Merinos (Piper et al., 1980), .57 in Galways (Hanrahan, 1980a), .50 in Finnsheep (Hanrahan and Quirke, 1982; 1985) and .30 in Romanov sheep (Ricordeau et al., 1986). Relatively high heritability estimates of ovulation rate and the possibility of repeated measurements of ovulation rate would suggest that selection for ovulation rate may increase litter size more rapidly than direct selection for litter size (Hanrahan, 1980a). However, previously published reports from several other species do not support the hypothesis that selection for ovulation rate alone will produce an increase in litter size. In Finnsheep (Hanrahan and Quirke, 1980; Hanrahan, 1982), mice (Land and Falconer, 1969; Bradford, 1969) and pigs (Cunningham et al., 1979), successful selection for ovulation rate has not increased litter size.

Litter size depends on ovulation rate and embryo survival. An

increase in ovulation rate without an increase in embryo survival may result in an increase in variability in litter size. This has been reported for selection studies with mice and pigs (Bradford, 1985) and a superovulation study in sheep (Ricordeau, 1988). The later study reported that the coefficient of variation for litter size in ewes treated with pregnant mare serum gonadotropin (PMSG) increased by 14 and 22% in Romanov and Finnsheep, respectively. The increased variation in litter size resulting from increased ovulation rate might be explained by the phenomenon of declining uterine efficiency as defined earlier.

Studies involving egg transfer between breeds have failed to show significant breed differences in uterine efficiency. Litter size of Welsh Mountain, Border Leicester and Finnsheep ewes each given four eggs averaged 2.6, 2.9 and 2.9, respectively (Bradford et al., 1974). Similarly, Hanrahan and Quirke, (1977) transferred 6 eggs to each of 25 Galway and 10 Finnsheep recipients. The corresponding mean litter sizes were 2.3 and 2.0, respectively. The difference was not statistically significant.

In another study, Bindon et al. (1978) found no difference in uterine efficiency following the transfer of three eggs each to Merino and Booroola Merino recipients which had mean natural ovulation rates of 1.5 and 4.0, respectively. Meyer and Clarke (1982) studied ovulation rate and the uterine efficiency of Ruakura fertility lines (High, Control) and selection lines of Romney (R), Border Leicester (BL) and R x BL ewes. Genetic differences between lines in litter size were due to ovulation rates with no evidence of genetic differences in uterine efficiency.

In contrast to the above results, Meyer et al. (1983) reported

genetic differences in uterine efficiency among several genotypes. Considering Romney as the standard among nearly 1000 non-synchronized naturally twin ovulating ewes, the ratios of uterine efficiency were 100, 114, 134, 122, 104 and 131 for Romney, Cheviot x Romney, BL x Romney, BL, Booroola x Romney and Booroola x Perendale genotypes, respectively. Romneys consistently produced fewer lambs than the other genotypes which produced 4 to 34 more lambs per 100 twin ovulating ewes. They also reported that at higher ovulation rates, increasing disproportionality of ovulation rate between ovaries resulted in lower litter size, possibly due to uneven distribution of implantation sites and increased losses due to crowding. Meyer (1985) re-examined the data of Meyer and Bradford (1973) which revealed that Finnsheep x Targhee ewes conceiving to twin ovulations produced 1.82 lambs vs 1.56 for Targhees, and for triplet ovulators mean litter sizes were 2.37 vs 1.83, respectively.

In summary, advances in litter size through selection are accompanied by advances in ovulation rate; however, the response in litter size to be expected following increases in ovulation rate is not clear and may depend on the genotype. This led Ricordeau (1988) to suggest that the best selection criteria for increasing number of lambs weaned per ewe is litter size at birth. Nevertheless, achieving improvements in reproduction through selection for either ovulation rate or litter size is a long term process.

By comparison, crossbreeding prolific breeds such as the Finn or Romanov with non-prolific breeds allows a rapid increase in ovulation rate in the crossbred compared to the non-prolific breeds (Hanrahan and Quirke, 1985; Ricordeau, 1988). The ovulation advantages from crossbreeding may

be due to either additive genetic effects or heterosis.

Fahmy and Dufour (1988) compared ovulation rate of various crosses between the Finn (F) and DLS (1/2 Dorset:1/4 Leicester:1/4 Suffolk) breeds. Compared to DLS ewes, ovulation rate advantages of the crosses increased from 5 to 85% as percentage Finn breeding increased from 13 to 88%. Ovulation rate was lowest for DLS and 1/8 Finn ewes (1.76 and 1.84), respectively, and highest for 7/8 Finn and pure Finnsheep (3.26 and 3.42), respectively.

Several studies have reported heterosis for ovulation rate. The study of Meyer and Clarke (1982) reported 11% heterosis for the ovulation rate in Border Leicester x Romney crosses over the parental breed midpoint. A 10% heterotic effect was seen for mating weights which may account for the observed increase in ovulation rate. Bradford and Quirke (1986) reported mean ovulation rates of 1.40, 2.04 and 2.04 for Targhee (T), Barbados (B) (1 to 4 year age) and B x T ewes (1 to 2 year age) respectively. The crossbred had 19% heterosis in ovulation rate compared to the mid parent average. In a study involving the Finnsheep and Galway breeds, Hanrahan (1974) found 32% heterosis in ovulation rate for 1/2 Finn:1/2 Galway hoggets and 14% heterosis for 1/4 Finn:3/4 Galway hoggets. Early maturity of the halfbred ewes probably accounted for the high heterosis in ovulation rate. For adult ewes, the Finn-Galway halfbred showed -11% heterosis in ovulation rate.

Contrary to the above results, Vesely and Swierstra (1986) in a study of crossbred ewe lambs of eight genotypes of various crosses of Dorset, Finn, Romanov and Western sheep found no significant heterosis for ovulation rate. Quirke et al. (1985) studied ovulation rate in T and W



Targhee lines (as defined earlier) and their reciprocal crosses. Ovulation rate for the first two cycles averaged 1.32 and 1.44 for W and T lines, respectively, while ovulation rate for reciprocal crosses averaged 1.38 which was equal to the mid parent value.

### ***Conception Rate:***

Conception rate is an indicator of fertility of a flock. Nitter (1978) defined it as the proportion of ewes lambing to ewes exposed to the rams. Many scientists have used the terms 'conception rate' and 'fertility' interchangeably. Generally, it has been observed that conception rate is higher for highly prolific and early maturing breeds. Early maturity of ewe lambs has been found to be a major contributor to their conception rate. Ewes having high ovulation rates as a result of selection have also been shown to have superior conception rates. Some evidence of difference in conception rate due to rams has also been published.

Finnsheep and Romanov are early maturing, highly prolific breeds used extensively in crossbreeding with non-prolific sheep breeds of the world to take advantage of their high reproductive potential. Maijala and Osterberg (1977) reviewed the performance of Finnsheep around the world. They reported 96% conception rate of Finnsheep in Finland, while the conception rate in Finnsheep in other countries was generally lower (74 to 94%).

Studies of the Ruakura (High, Control and Low lines) fertility flocks provide evidence of higher conception for High than Low lines (Clarke, 1972). Conception rates were 93, 89 and 84% for High, Control

and Low lines, respectively.

The study of Bradford et al. (1986a) strengthens the evidence of higher conception for high fertility lines. They studied 444 ewes of two age groups from five lines of Targhee sheep: two control (C) lines, two lines (W) selected for 20 years for 120 day weight, and a line selected for 19 years for litter size (T). At the first service, the conception rates were 78, 73 and 66% for T, C and W lines, respectively. Cumulative conception from all services showed similar values, being 91, 90 and 88% for T, C and W lines, respectively. Among mature ewes, conception was 13% higher ( $P < .05$ ) for ewes with two vs one corpus luteum (CL). Twin-ovulating ewes with one CL on each ovary had higher conception rates than those with both CL on one ovary.

Meyer's (1985) review of several studies suggested advantages in conception rates for multiple-ovulators, regardless of their genotypes. All studies cited by the above author showed conception rate advantages, ranging from 1 to 15% for twin-ovulators.

The results of crossbreeding studies have suggested relatively higher conception rate in crossbred ewes than in purebred ewes. Much of the crossbreeding research involving the Finn and US breeds has shown 0 to 30% heterosis in conception rate. Jakubec (1977) reported that crossing the Romanov with indigenous sheep breeds of European countries has resulted in a 16 to 50% higher conception rate in the crossbreds than in the local breeds. Early maturity and high conception rates in ewe lambs are typical Finn and Romanov breed features transmitted to crossbred progeny. Crossbred conception rates as adult sheep are similar to other breeds.

Sidwell and Miller (1971) reported 2 to 28% heterosis in conception rate in the crossbred daughters resulting from crosses between Hampshire, Columbia, Southdale, Targhee, Suffolk and Dorset breeds of sheep. Fahmy (1982) compared the maternal performance of mature ewes representing Oxford, Suffolk, Oxford x Suffolk, Suffolk x Oxford, Cheviot x Oxford and Cheviot x Suffolk genotypes mated to purebred and crossbred rams. Although the effect of purebred vs crossbred rams was not studied, the conception rate was 7 to 10% higher (heterosis) for crossbred ewes than for purebred ewes. The heterosis for conception rate in Suffolk and Oxford reciprocal crosses was 10%. Oxford crossbred ewes were more fertile than pure Oxford ewes by 9%. Similarly, Suffolk crossbred ewes were 7% more fertile than pure Suffolk ewes.

Long et al. (1989) compared Suffolk and Targhee ewes to their reciprocal crosses. To estimate maternal heterosis, F1 ewes were backcrossed to rams of their dams' breed. They found 1% individual heterosis and 3% maternal heterosis for conception rate. This compares to 3% individual heterosis and 9% maternal heterosis for conception rate reported by Nitter (1978) who suggested that high estimates of heterosis reported from studies with young ewes were due to earlier maturity. For instance, Laster et al. (1972) found 11% advantage in conception rate of half Finnsheep ewe lambs over half Rambouillet ewe lambs, and Land et al. (1974) reported very high heterosis (88%) in ewe lamb conception rates among reciprocal crosses of Finnsheep and Merinos.

Dickerson and Laster (1975), in a study of Finn and Rambouillet crosses with Suffolk, Hampshire, Coarse wool, Corriedale, Dorset and Targhee sheep, found significantly lower ( $P < .05$ ) age at puberty for Finn

crosses (219 days) vs Rambouillet crosses (238 days).

Vesely and Swierstra (1986) in a study of 8 genotypes involving Dorset, Finn, Romanov and Western sheep and their crossbreeds reported that Romanov crossbred ewe lambs conceived about 3 weeks earlier than Finn crosses. In contrast, Cedillo et al. (1977) found no difference in age at first estrus between crossbred ewe lambs sired by Finn rams versus those sired by Dorset, Targhee, Corriedale or coarse wool rams. However, a significant difference in ewe lamb fertility was observed between Finn crosses (72%) and non-Finn crosses (38%).

Thomas and Whiteman (1979) used crossbred ewe lambs representing four combinations of Finnsheep (F), Dorset (D) and Rambouillet (R) breeding to look at the main effects of increasing Dorset and Finnsheep breeding by 1/4 at the expense of Rambouillet breeding. The comparison of 1/2 Dorset ewes with 1/4 Dorset ewes estimated the main effect of increasing Dorset breeding by 1/4 at the expense of Rambouillet breeding (1/4 Dorset effect) and the comparison of 1/4 Finnsheep ewes with 0 Finnsheep ewes estimated the effect of increasing Finnsheep by 1/4 at the expense of Rambouillet breeding (1/4 Finnsheep effect). The crossbred ewes of 1/2D:1/2R, 1/4D:3/4R, 1/4F:1/2D:1/4R and 1/4F:1/4D:1/2R composition had 60, 53, 84 and 77% fertility, respectively. The 1/4 Finnsheep effect resulted in a significant increase of 24% in fertility while the 1/4 Dorset effect resulted in a non significant increase of 7% in fertility.

Oltenacu and Boylon (1981) reported 95, 51, 75 and 90% fertility for purebred Finn, Targhee, Minnesota 100 and Suffolk ewe lambs, respectively. The levels of fertility for F1 females of Finn crossed with Targhee,

Minnesota 100 and Suffolk were 95, 94 and 87%. The heterosis estimates for fertility in the respective F1 females were 30, 11 and -6%. The authors reported that fertility increased from 79 to 92% as the proportion of Finn genes increased from 1/4 to 3/4 in the crossbred ewes. Cochran et al. (1984) also reported increased conception rates as the proportion of Finn genes increased in the crossbred. The conception rates for pure Dorset, 1/4 Finn and 1/2 Finn crosses with Dorset were 80, 88 and 94%, respectively.

Cameron et al. (1983) compared conception rates of crossbred ewes sired by Border Leicester(BL), Bluefaced Border Leicester(BFL) and Damline (DL) rams. The Damline was developed by combining the Finn, East Friesian, Border Leicester and Dorset breeds in the proportions of 0.47, 0.24, 0.17 and 0.12, respectively. The conception rate for one year old crossbred ewes was highest for DL (0.78) compared to BFL (0.73) and BL (0.62) sired ewes, suggesting earlier sexual maturity in DL-sired ewes. Conception rates for all groups were similar at 2 and 3 years of age.

Lewis and Burfening (1988) reported higher conception rate ( $P<.01$ ) for 1/4 Finn than for Whiteface (Columbia, Rambouillet, Targhee) ewe lambs (38% vs 1%). This was due to greater sexual development of ewes mated at 7 months of age to lamb at one year of age. Mature (2 to 6 year old) 1/4 Finn cross ewes had similar fertility to mature Whiteface ewes. Similar results were reported by Fahmy and Dufour (1988) who found a 65% conception rate in the DLS (1/2 Dorset:1/4 Leicester:1/4 Suffolk) ewe lambs compared to 89% for purebred Finnsheep with the crosses being intermediate. Conception rate in older ewes was similar in all genetic groups (average 94%).

Fogarty et al. (1984) in a comparison of five pure breeds of sheep (Finnsheep,F; Rambouillet,R; Dorset,D; Targhee,T; Suffolk,S) and their crosses in the development of two maternal synthetic lines ( $C1=1/2F:1/4R:1/4D$  and  $C2=1/2F:1/4T:1/4S$ ) reported that all crossbred genotypes were superior to the purebred ewes in fertility. Heterosis in fertility was positive and highly significant ( $P<.01$ ) for all generations of crosses, ranging from 17 to 27% with little indication of decline from the C1 and C2 three breed crosses to the first inter se generations.

Jakubec et al. (1977) reported that ewes derived from the Mutton Merino crossed with East Friesian Milkshewp or Finnsheep had a lower fertility in ewe lambs and slightly higher fertility in the adult ewes than crossbreds derived from Romanov rams. Their citation of Fox et al., (1976) reported 5% heterosis in conception rate among  $1/2$  Awassi: $1/2$  Chios ewes. Young et al. (1986) cited Spanish studies conducted by Sierra (1980, 1982) who found significant heterosis (27%) in conception rate for  $1/2$  Romanov: $1/2$  Aragon ewes during spring mating; however, in fall matings heterosis was only 5%.

In a South African study, Greef et al. (1988) compared the conception rate of Romanov, Dorper (Dorset horn x Black Persian) and their reciprocal F1 and F2 crosses. F1 ewe lambs and mature ewes had 12 and 4% heterosis in conception rate. The F2 ewe lambs from reciprocal crosses of the F1 had 12% heterosis in conception rate. In contrast, Weiner and Hayter (1975) when comparing Blackface Cheviot, Welsh and their F1 crosses did not find differences in conception rates among genotypes. Similarly, Magid et al. (1981) found similar fertility at 1 to 3 years of age for Border Leicester and Finn-sired ewes (67 and 68%, respectively) from

Hampshire, Rambouillet, Targhee and 1/2 Finn dams.

Little research information has been published concerning the significance of breed of ram on conception rate; however, a few studies suggest there may be a difference. For instance, Land et al. (1974) reported results of a study involving the Finn and Merino breeds and their reciprocal crosses where breed of ram had a direct effect on conception rate of the ewes to which they were mated. Twenty two percent of ewes mated to Merino rams returned to estrus compared to 10% of those mated to Finn rams. Leymaster (1987), in his review, reported 1% paternal heterosis for seasonal fertility and very high (30%) paternal heterosis in fertility during spring breeding.

Contrary to the above results, Bradford (1963) found negative heterosis in fertility (-4%) when Hampshire x Suffolk F1 rams were compared to purebred Hampshire and Suffolk rams in mating with Whiteface ewes.

Since limited numbers of rams have generally been used per genetic group, it is difficult to conclude whether or not crossbred rams have any real advantage over purebred rams in terms of conception rate.

### ***Litter Size:***

Litter size is one of the most important reproductive traits affecting profitability of sheep production. It depends on ovulation rate, conception rate and embryo survival and is defined as the number of lambs born (dead or alive) per ewe lambing. Since litter size is an important contributor to profitability, much attention has been given to increasing litter size. Bradford (1985) suggested three methods to

improve litter size in sheep:

- 1: Selection within breeds for increased litter size or traits correlated with litter size;
- 2: Use of prolific breeds such as Finn and Romanov sheep in crossbreeding with non-prolific breeds;
- 3: Introduction of major genes such as the Booroola 'F' gene into other breeds by crossbreeding.

Selection response in litter size depends on heritability and the selection differential. Heritability estimates reported for litter size in sheep include: 0.15 (Turner, 1969), 0.10 (Hanrahan, 1980a), 0.11 (Forgarty et al., 1985), 0.12 (Clarke and Hohenboken, 1983) and 0.10 (Bradford, 1985).

Based on the above estimates, it is obvious that heritability of litter size in sheep is quite low. However, phenotypic variability is relatively high, resulting in potentially high selection differentials. The high selection differential permits sizeable annual response to selection, even with low heritability. Many selection experiments for litter size have shown significant improvements over time. Some reported annual responses for increased litter size include: 1.1% in Romneys (Wallace, 1964); 2.3% in Merinos (Turner, 1978); 1.8% in Merinos (Atkin, 1980); and 1.5% in the Irish High fertility breed (Hanrahan, 1982). While the above experiments showed significant improvements in litter size due to selection, it is a time-consuming technique and produces relatively slow gains in litter size per year.

In contrast to selection, crossbreeding with highly prolific breeds such as the Finn and Romanov may be the most efficient way to improve



litter size. Improvement in litter size from crossbreeding is due to additive and/or heterotic effects. Synthetic lines developed following crossing have also shown substantial increases in litter size.

In a review of productivity of pure Finnsheep in several countries of the world, Maijala and Osterberg (1977) reported that mean litter sizes at birth for 1 year old, 2 year old and adult ewes are 1.84, 2.45 and 2.82, respectively. They also reported that Finnsheep ewes have given an average of 60% larger litters than Texel, 70% larger than Galway, 130% larger than Minnesota 100, and 80% larger than Suffolk ewes when managed under the same conditions.

Black (1982) reported high reproductive performance for a Coopworth ram- breeding flock in New Zealand. Over a ten year period litter size ranged between 1.70 and 2.05 with 24% of the ewes having three or more lambs. Similarly, in a study in the Southern South Island of New Zealand, Rohloff et al. (1982) identified six commercial Coopworth flocks achieving mean litter sizes in excess of 1.80 lambs per litter. Davis et al. (1987) compared highly prolific flocks of Romney, Coopworth and Perendale sheep (established at Woodland research station in the South Island by gathering screened animals from registered and non registered flocks throughout New Zealand). Mean litter sizes for 1.5 year old Romney, Coopworth and Perendale ewes were 1.63, 1.87 and 1.61, respectively, and for older ewes the respective litter sizes were 1.88, 1.94 and 1.78 lambs. Coopworth mean litter size at 1.5 years of age was .24 and .26 larger ( $P < .01$ ) than Romneys and Perendales, respectively. Litter size differences between breeds were less in older ewes; the only significant difference ( $P < .01$ ) was the larger litter size of Coopworths compared with Perendales (.16

lambs).

A number of studies have demonstrated that crossing highly prolific breeds such as the Finn and Romanov with other sheep breeds increases litter size in the crossbreds in an additive manner. Dickerson (1977) in a study of Finnsheep contribution in various crosses with US sheep breeds, reported that litter size increased an average of 1% for each percent of Finnsheep breeding in crossbred ewes. Magid et al. (1981) compared the performance of Finn and Border Leicester-sired ewes (1 to 3 years of age) in matings with Suffolk rams. Mean litter sizes at birth were 1.78 and 1.39 for Finn-sired and Border Leicester-sired ewes, respectively ( $P < .05$ ). In another study of Finn crossbreeding, Cochran et al. (1984) compared the performance of 1/2 Finn:1/2 Dorset, 1/4 Finn:3/4 Dorset and purebred Dorset ewes from 1 to 3 years of age. Litter size was highest ( $P < .01$ ) for 1/2 Finn (1.97) followed by 1/4 Finn (1.74) and Dorset (1.44) ewes.

Saoud (1984) reported performance of F1 ewes from Panama-type dams and Clun Forest, Dorset, Border Leicester, Polypay and Suffolk sires. Respective mean litter sizes were 1.50, 1.71, 1.76, 1.67 and 1.60 and did not differ significantly.

The performance of Rambouillet (R), Dorset (D), Finnsheep (F) and F1 (RD, RF and DF) ewes managed in a semi confinement winter lambing system was evaluated by Iniguez et al. (1986). Finns and Finn crosses had significantly higher litter size than purebred Rambouillets. Overall mean litter size for R, D, and F ewes was 1.30, 1.55 and 2.09 lambs, respectively. The mean litter sizes for crossbred RD, RF and DF ewes were 1.44, 1.73 and 1.65, respectively. RD and RF ewes were almost intermediate to the mid parent values whereas DF ewes had 9% lower litter

size than their mid parent value.

Vesely and Swierstra (1987) compared ewe lambs of 6 genotypes generated by mating 3/4 Dorset and 3/4 Finn dams to Dorset, Finn and Romanov sires. Mean litter sizes of ewe lambs sired by Dorset, Finn and Romanov sheep were 1.36, 1.87 and 2.12, respectively. Ewe lambs sired by Finn rams had significantly higher (38%) litter size than ewe lambs sired by Dorset rams. Ewe lambs sired by Romanov rams had significantly higher (13%) litter size than ewe lambs sired by Finn rams; however, the absence of ewes with Romanov breeding precludes determining whether this difference was due to additive or heterotic effects. The litter size of 3/4 Finn ewes was significantly higher than for 3/4 Dorsets (2.01 vs 1.55).

Fahmy and Dufour (1988) reported mean litter sizes for DLS (1/2 Dorset: 1/4 Leicester:1/4 Suffolk) and Finn ewes of 1.44 and 2.86, respectively. Among the seven Finn and DLS crosses included in the study, mean litter size increased progressively from 1.63 for 1/8 Finn to 2.42 for 7/8 Finn ewes. Lewis and Burfening (1988) compared litter size in mature Whiteface (Columbia, Rambouillet, Targhee) ewes with 1/4 Finn ewes. The 1/4 Finn ewes averaged .36 more lambs per litter ( $P < .01$ ).

Crossbreeding results involving only US sheep breeds also show heterotic effects in litter size. In a study of 20 different crosses involving the Hampshire (H), Columbia (C), Targhee (T), Suffolk (S) and Dorset breeds, Sidwell and Miller (1971) found 3% heterosis for litter size. Fourteen out of 20 crosses showed positive heterosis while in 6 crosses negative heterosis was observed. The most heterosis in two way crosses were 18, 15, 13 and 11% in D x T, H x D, H x T and T x S

crosses. Land et al. (1974) in a study of Finn, Merino and reciprocal cross ewes, found 30% heterosis in litter size for ewe lambs. However, mean litter sizes for 2 to 4 year old ewes averaged 2.68, 1.70, 1.70 and 1.00 for Finn, Finn x Merino, Merino x Finn and Merino, respectively, with no evidence of heterosis. Wiener and Hayter (1975) compared litter size of ewes of Scottish Blackface (B), Cheviot (C), Welsh Mountain (W) and B x C, B x W and C x W crosses. Crossbred ewes had 12% higher litter size than their parental mean. Nitter (1978) in a review, reported both mean individual and maternal heterosis, estimates for litter size were 3%. Fahmy (1982) compared the performance of Oxford, Suffolk, their reciprocal cross and Cheviot x Oxford and Cheviot x Suffolk crossbred ewes. He found 9% heterosis in litter size in the reciprocal cross of Oxford x Suffolk ewes. Oxford crossbred ewes resulted in much improved litter size of 19% compared with the pure Oxford ewes. However, the Suffolk crossbred ewes had -1% heterosis for litter size. In this study, all crossbred ewes were collectively 8% superior to purebred ewes in litter size.

Bradford and Quirke (1986) compared performance of Barbados (B), Targhee (T) and B x T ewes. Respective mean litter sizes were 1.71, 1.28 and 1.84. The F1 B x T ewes were significantly (23%) superior to the mid parent average for litter size.

Baker et al. (1987) reported results of a study in which Border Leicester, Coopworth and 6 strains of Romney rams from different sources were mated to Romney ewes. Litter size of F1 ewes sired by Border Leicester and Coopworth rams averaged 1.71 and 1.70, respectively. Litter size for F1 ewes sired by rams of 6 Romney strains ranged from 1.39 to 1.68. Coopworth and Border Leicester crosses had an average advantage of

25 lambs born per 100 ewes lambing relative to the 6 Romney strains.

Gallivan et al. (1987) reported 16% individual and 15% maternal heterosis for litter size in crosses involving the Columbia, Targhee, Hampshire and Finn breeds. Long et al. (1989) reported 3% individual heterosis and 7% maternal heterosis for litter size among matings of the Targhee and Suffolk breeds.

Development of synthetic lines from crossbreeding of two or more appropriate breeds generally results in improved litter size. Sidwell et al. (1962) compared Hampshire, Shropshire, Southdown, Merino and Columbia-Southdale sheep with a variety of their 2, 3 and 4 breed crosses. Litter size averaged 1.37, 1.28, 1.48 and 1.49 for purebreds, 2 breed, 3 breed and 4 breed crosses, respectively. Litter size was about 8% higher in 3 breed and 4 breed crosses than in purebreds.

Thomas and Whiteman (1979) reported the performance of crossbred ewes composed of 1/2 Dorset:1/2 Rambouillet, 1/4 Dorset:3/4 Rambouillet, 1/4 Finn:1/2 Dorset:1/4 Rambouillet and 1/4 Finn:1/4 Dorset:1/2 Rambouillet genes; litter sizes at one year of age averaged 1.11, 1.05, 1.16 and 1.18, respectively. The corresponding values for ewes averaged over 2 and 3 year of age were 1.60, 1.53, 1.67 and 1.62. Both the 1/4 Finnsheep (comparing 1/4 Finnsheep ewes with 0 Finnsheep ewes) and 1/4 Dorset effects (comparing 1/2 Dorset with 1/4 Dorset ewes) were positive but non significant for litter size.

Oltenacu and Boylan (1981) compared litter size in four pure breeds (Finnsheep, Suffolk, Targhee and Minnesota 100), the F1 crosses between Finnsheep rams and females of the other three breeds and F2 and backcross ewes. Litter sizes averaged over the first three years of age were 2.52,

1.08, 1.40 and 1.28 for Finnsheep, Minnesota 100, Suffolk and Targhee ewes, respectively. F1 ewes were more prolific than their respective standard breeds with average litter size of 1.80. The litter size for 3/4 Finnsheep ewes averaged 1.94, higher than purebred standard breeds. However, the litter size of F2 ewes was lower than for F1 ewes and averaged 1.68.

Hulet et al. (1984) looked at mean litter size (lambs born/ewe exposed) of Polypay, Targhee, 1/2 Dorset:1/2 Targhee and 1/2 Finn:1/2 Rambouillet genotypes each mated inter se. Respective mean litter sizes in winter from ewes 2 years or older were 1.43, 1.37, 1.28 and 1.72. During the summer lambing season the mean litter sizes in the above order were 0.79, 0.48, 0.60 and 0.45 lambs per ewe exposed. During winter lambing mean litter size of Finn-Rambouillet ewes was superior ( $P<.05$ ) to other breed groups. However, during the summer lambing season the respective performance of Polypays was superior ( $P<.05$ ) to the other genotypes, suggesting out of season breeding may be a useful character of the Polypay breed.

Fogarty et al. (1984) compared performance for Finnsheep(F), Rambouillet(R), Dorset(D), Targhee(T) and Suffolk(S) ewes and various breed crosses produced in the development of two maternal synthetic lines(C1= 1/2F:1/4R:1/4D and C2=1/2F:1/4T:1/4S). Mean litter size for genotypes creating the C1 synthetic were: 2.55 for Finnsheep; 1.56 for Rambouillets; 1.55 for Dorsets; and 2.10 for F x R and F x D crosses. Heterosis for litter size was 4% ( $P<.05$ ) in C1 three breed cross. For breeds contributing to the C2 synthetic, litter size in Suffolk and Targhee ewes was 1.56 and Finn crosses (1/2F:1/2S and 1/2F:1/2T) averaged

2.13, intermediate between their parental breeds. The 1/2F:1/2S ewes produced .15 lambs more than 1/2F:1/2T ewes and averaged 4% ( $P < .05$ ) above their parental mean, but heterosis for litter size was negligible in the C2 three breed cross.

Contrary to the above, Vesely and Peters (1974) found no significant improvement for litter size in two breed and three breed crosses involving Romnelet, Columbia, Suffolk and North Country Cheviot breeds. Litter size was highest (1.34 to 1.59) for ewes between 3 and 5 years of age and lowest (1.07) for yearling ewes. Iniguez et al. (1986) found negative heterosis in litter size from crossbred ewes. Litter size results averaged over two replicate groups of Rambouillet x Dorset and Dorset x Finn ewes showed heterosis of -20 and -16%, respectively, compared to the mid parent average.

Major genes such as the Booroola 'F' gene can have a significant impact on prolificacy. Through crossbreeding, major genes can be introduced to improve prolificacy of non prolific sheep breeds. Once the gene is introduced, benefits may result from using repeated backcrossing to remove the Booroola genes from the crossbred population. Metherell (1984) found the same mean litter size (2.28 vs 2.29) among 1/2 Booroola:1/2 Coopworth and 1/4 Booroola:3/4 Coopworth genotypes, respectively, as against a mean litter size of 1.73 in pure Coopworths. Weaning weight for lambs from 1/2 Booroola:1/2 Coopworth, 1/4 Booroola:3/4 Coopworth and purebred Coopworths were 21.9, 22.9 and 23.6 kg, respectively. The high litter size and lamb weaning weights for 1/4 Booroola:3/4 Coopworth ewes suggest that the advantage of high prolificacy due to a major gene can be obtained without sacrificing growth and wool

characteristics. In a similar study, Davis (1985) reported a mean litter size of 1.92 for 1/8 Booroola:7/8 Coopworth ewes compared with a mean litter size of 1.48 for contemporary Coopworths on the same farm.

### ***Lamb Survival:***

The improvement in biological and economical efficiency of sheep production is much greater from increasing number of lambs weaned per ewe than from growth rate (Dickerson, 1978). Survival to weaning has major effects on number of lambs weaned per ewe, and its genetic correlation with weight weaned per ewe is high (Fogarty et al., 1985). Birth weight, litter size and breed all have significant effects on lamb survival to weaning.

Oltenacu and Boylan (1981) reported 93, 85 and 78% survival for single, twin and triplet born lambs. Similarly, Saoud et al. (1984) found lamb survival rates of 88, 81 and 61% for lambs born as singles, twins and triplets, respectively. Rohloff et al. (1982) reported that lamb mortality (lambs dead/lambs born) ranged from 9% for Coopworth flocks with 1.30 to 1.39 mean litter size to 14% for flocks with mean litter sizes above 1.70. Triplets and quadruplets had significantly greater mortalities (18 and 28%) than either single (9%) or twin born (7%) lambs.

Purser and Young (1964) suggested that birth weight of lambs, rather than their litter size, has the major affect on preweaning lamb survival because lambs of equal birth weight had equal survival regardless of type of birth. Birth weight of twin born lambs is typically 15 to 20% less than for singles, and triplets are 30 to 35% lighter than single born lambs (Purser and Young, 1964; Bradford 1972b; Magid et al., 1981a;



Rastogi et al., 1975; Oltenacu and Boylan, 1981b).

On average, single born lambs have higher birth weights than twins and triplets, and hence are more prone to dystocia. Triplets, on the other hand have lighter average birth weights than twins and singles and are more subject to physiological starvation. Mortality is higher in lambs experiencing dystocia than in those born without difficulty (Smith, 1977).

Clarke (1972) compared survival rates (lambs docked/lambs born) of lambs from selection lines in the Ruakura fertility flock. The survival rates for the High, Control and Low lines were 78, 78 and 88%, respectively, and were not adjusted for birth rank. Although lambs of the High line were 10% inferior in survival to the lambs of the Low line, High ewes weaned 27% more lambs/ewe lambing than Low ewes.

Fahmy (1980) compared Nfld (a native breed to Newfoundland) and DLS (1/2 Dorset:1/4 Leicester:1/4 Suffolk) genotypes at Nappan, Nova Scotia. Perinatal survival (to 24 hour) was 8% lower among the DLS (85%) than Nfld (93%) sheep. Of the DLS lambs alive at 24 hours, only 81% were weaned compared to 94% of Nfld lambs. As a result, overall lamb survival was 87% for Nfld ewes vs 69% for DLS ewes, and Nfld ewes weaned nearly .25 more lambs per ewe. DLS yearlings contributed to the poor performance of this breed; about one-half the lambs born to yearlings died before weaning.

Hulet et al. (1984) compared litter size at birth with litter size at weaning in Polypay, Targhee, 1/2 Dorset:1/2 Targhee and 1/2 Finn:1/2 Rambouillet ewes. Respective survival rates were 77, 78, 77 and 65% during winter lambing. The corresponding values during summer lambing were 78, 67, 68 and 76%. Polypay lambs had the highest average survival

(78%) and 1/2 Finn:1/2 Rambouillet lambs had the lowest (72%). In winter lambing, lambs born per ewe exposed averaged 1.72 and 1.43 for 1/2 Finn:1/2 Rambouillet and Polypay sheep, respectively; however, due to better lamb survival in the Polypay breed, the average numbers of lambs weaned per ewe exposed were similar (1.11 and 1.10).

In another study, Saoud et al. (1984) reported mortality rates of 16, 24, 14, 19 and 21% for crossbred lambs from Panama-type dams in matings with Clun Forest, Dorset, Border Leicester, Polypay and Suffolk sires. All matings had produced similar mean litter sizes ranging from 1.62 to 1.71.

From surveys of commercial sheep farms in Britain, Wiener et al. (1973) reported that average survival rates among lambs from crossbred daughters of North Country Cheviot, Suffolk and Finnsheep x Dorset rams were 84, 91 and 94%, respectively. Dickerson et al. (1975) reported -5% heterosis for mortality in crossbred lambs from reciprocal crosses among Hampshire, Dorset, Rambouillet and coarse wool breeds. Heterosis in Finn crosses with Suffolk, Hampshire and Dorset was -12 to -21% for lamb mortality to 10 weeks.

Smith (1977) reported results of a study in which Suffolk, Oxford and Hampshire rams were mated to purebred (Suffolk, Hampshire, Rambouillet, Dorset, Targhee, Corriedale and Coarsewool), Rambouillet cross and Finn cross ewes. Suffolk-sired lambs had 9% higher mortality rates than those from Oxford sires while Hampshire-sired lambs were intermediate.

Meyer et al. (1977) found slightly higher preweaning survival (about 3%) for Finn x Romney lambs compared to their purebred parental

average. Nitter (1978), in his review, reported an average of 10% superiority in preweaning survival of crossbred lambs over purebred lambs. He suggested that increased viability was one of the main advantages of crossbred lambs compared with purebred lambs. Although relatively low, an additional maternal heterosis component of 3% for preweaning survival was also reported.

Oltenacu and Boylan (1981) compared preweaning lamb survival from purebred Finn, US (Minnesota 100, Suffolk and Targhee) breeds, and F1 lambs from crossing Finns with the US breeds. Overall, F1 lambs were 4% superior to the average lamb survival of the US breeds while F2 lambs (91% survival) were superior to the purebred and F1 lambs by 10 and 7%, respectively, suggesting both individual and maternal heterosis for lamb survival.

Magid et al. (1981a) compared the performance of crossbred ewes (1 to 3 years of age) produced by mating Finn and Border Leicester sires to Hampshire, Rambouillet, Targhee and 1/2 Finn dams. They reported that when data were adjusted for type of birth or rearing, lambs of Finn-sired ewes had 14% higher survival to weaning than lambs from Border Leicester-sired ewes (65 vs 51%). Dam breed of ewe also influenced lamb survival. It was highest (68%) for lambs from daughters of 1/2 Finn dams, lowest (49%) for those from Rambouillet dams and intermediate (57 and 58%) from Hampshire and Targhee dams.

In a British study, Cameron and Deeble (1983) reported respective preweaning survival rates of 90, 92 and 87% for Border Leicester, Bluefaced Leicester and Damline-sired lambs produced from Welsh Mountain ewes. Their respective litter sizes at birth averaged 1.38, 1.54 and 1.33

and their litter sizes at weaning ranked in the same order as litter size at birth.

In another British study, Mann et al. (1984) reported results from daughters produced by mating Scottish Blackface ewes to Blackface, Border Leicester, Cambridge, East Friesian, Oldenberg and Texel sires in Scotland. Respective survival rates of lambs from these crossbred ewes were 89, 89, 83, 91, 90 and 92% and corresponded to respective litter sizes of 1.56, 1.77, 2.01, 1.97, 1.63 and 1.56. Cambridge cross ewes had the highest litter size at birth; however, East Friesian cross ewes weaned the highest average number of lambs.

Fogarty et al. (1984) studied preweaning lamb survival in Finnsheep(F), Rambouillet(R), Dorset(D), Suffolk(S), Targhee(T), Finn cross (F x S, F x T, F x R, F x D) and two synthetic dam lines ( $C1=1/2F:1/4R:1/4D$ ;  $C2=1/2F:1/4S:1/4T$ ). Heterosis in preweaning survival ranged from 11 to 14% for the Finn crosses versus 15 and 25% for the two synthetic lines.

Iniguez et al. (1986) found 0, 3 and 20% heterosis in survival for single born lambs from Rambouillet x Dorset, Dorset x Finn and Rambouillet x Finn ewes. The corresponding heterosis values for twin born lambs were 10, -12 and 3%, respectively. Overall, lambs from crossbred ewes showed better survival than lambs from purebred ewes.

Fahmy and Dufour (1988) reported preweaning mortality rates for lambs from DLS ( $1/2$  Dorset: $1/4$  Leicester: $1/4$  Suffolk) and Finn ewes and their 7 combinations ranging from  $1/8$  Finn to  $7/8$  Finn. Mortality rates for purebred lambs from DLS and Finn ewes were 14 and 23%, respectively. Although lamb mortality increased progressively from 10 to 17% for lambs

from 1/8 Finn to 7/8 Finn ewes, the number of lambs weaned also increased from 1.44 to 1.91 as the proportion of Finn genes increased. Although mortality rate was highest (23%) in lambs from purebred ewes, average litter size at weaning was also highest at 2.03 lambs per ewe lambing. Barker (1975), reporting results from British field data, also found higher lamb mortality accompanying the higher lambing percentages of Finnsheep crossbred ewes compared to crossbred ewes of other types.

Hohenboken and Clarke (1981) produced eight genotypes by mating Suffolk and Columbia type ewes to Cheviot, Dorset, Finnsheep and Romney sires. The resulting crossbred ewes were then mated to Hampshire rams in two management systems-hill pasture and irrigated pasture. Within both management systems, lambs from Finnsheep crossbred ewes had 5 to 15% lower survival rates than lambs from the other groups, however survivability of lambs from Finnsheep crossbred ewes was biased downward because all lambs in excess of 2 were removed from the dams and considered as dead. Lambs from Suffolk crossbred ewes had a survival rate on hill pasture of 77% compared to 83% for lambs from Columbia crossbred ewes; respective values on the irrigated pasture were 80% and 81%. Although the differences favored Columbia crosses in both management systems, they were not statistically significant.

Thomas and Whiteman (1979) reported preweaning lamb survival over 3 years from ewes of 1/2 Dorset:1/2 Rambouillet, 1/4 Dorset:3/4 Rambouillet, 1/4 Finn:1/2 Dorset:1/4 Rambouillet and 1/4 Finn:1/4 Dorset:1/2 Rambouillet composition. Survival rates in the above order averaged 90, 87, 79 and 86%, respectively.

Based on a review of several research studies, Bradford and Meyer

(1986) indicated that breeds of larger mature size generally transmit lower viability. The differences were quite large in several cases, often more than offsetting substantial advantages in lamb growth for larger breeds. For example, their citation of Dickerson (1977) showed that Suffolk-sired crossbred lambs produced 9% more meat per lamb than Oxford-sired crossbred lambs, but 11% less meat per ewe due to higher mortality of Suffolk crosses.

It is apparent from the above review that crossbred lambs generally have higher survival than purebred lambs, this advantage coming from both individual and maternal heterosis. Choice of breeds used in the cross affects lamb survival to weaning. Crossbreeding studies involving prolific and non-prolific breeds indicate that mortality increases as litter size increases; however, the net effect is still usually an increased number of lambs weaned. Research studies have also indicated that lambs from terminal sire breeds have relatively lower survivability, suggesting that breeds of large mature size transmit lower viability.

#### ***Lamb Weaning Weights:***

It is well known that weaning weight is affected by many factors including breed, sex, litter size, rearing rank, age of dam, age of lamb, nutrition, season and management (Sidwell and Miller, 1972; Oltenacu and Boylan, 1981; Bradford, 1972b). Therefore, a wide range in weaning weights of lambs exists. Among the above factors, litter size is the most important, and studies uniformly indicate that increasing litter size has a negative effect on individual weaning weight.

Bradford (1972b) reported that the effect of rearing rank on lamb

weaning weights also has a permanent environmental effect on mature weight. Doney and Munro (1962) suggested that weaning weight may not be a function of birth rank but rather of birth weight. They observed no difference in weaning weight between singles reared as singles and twins reared as singles when both were adjusted for birth weight. Oltenacu and Boylan (1981) reported that compared to lambs born and raised as twins, lambs born and reared as singles were 33% heavier at weaning while lambs born as twins but reared as singles were 10% heavier.

Sheep producers have given much attention to weaning weight of lambs with the perception that more rapid growth results in improved efficiency of lamb production. Parker and Pope (1983) reported that slaughter weights had increased an average of .31 kg per year during the previous 25 years while the average annual change in lamb slaughter weight per breeding ewe in the USA during this period was 4.5 times greater than the average increase in lamb crop percentage. The increases in weight were attributed to use of larger breeds for slaughter lamb production, selection emphasis on body size within breeds and feeding lambs to heavier slaughter weights.

Studies of long term selection for increased body weight have not shown encouraging responses in overall increased productivity. For instance, Lasslo et al. (1985) reported that from a common base population of Targhee sheep, two lines (HW & DH) kept under range conditions at the Hopland station and a line (DW) kept under irrigated pasture at Davis were selected for 120 day weaning weight for 17 years and 20 years, respectively. Relative to controls at each location, the estimated increases in 120 day weight for single lambs were 9.25, 4.02 and 6.39 kg

for lines DW, HW and DH, respectively. The improvements in 120 day weight for twin lambs in lines DW, HW and DH were 7.14, 1.83 and .61 kg, respectively, as compared with their respective control lines. At Davis, there was a significant response in 120 day weight in both single and twins, whereas at Hopland significant response was achieved only in single born lambs, suggesting higher direct response to 120 day weaning weight selection under irrigated pasture conditions than under range conditions. In spite of significant direct response to selection in both environments, decreases in lamb survival and fertility resulted in none of the selected lines producing more total weight weaned per ewe than their respective control lines. The study indicates that selection for growth rate to weaning results in heavier lambs but does not increase, and may actually decrease, total lamb production per ewe.

Adverse effects of increased growth rate as a result of selection have also been reported in poultry. Verghese and Nordskog (1968) reported significant direct response in body weight when Leghorn and Fayoumi lines were selected for high body weight for 5 generations; however, significant correlated declines were observed in traits such as egg production, fertility, hatchability and, to some extent, pullet survival to 9 month of age. The net effect was a decline in meat production per breeding female.

Crossbreeding may be more useful than selection for producing heavier lambs. A number of crossbreeding studies have suggested that crossbred lambs grow faster than purebred lambs. Lambs from crossbred dams may also benefit from increased milking ability of their dams and thus exhibit relatively higher weaning weights. Benefits of crossbreeding may also result from using terminal sire breeds such as Suffolk and



Hampshire to produce heavier lambs at weaning. In spite of relatively lower viability of lambs of terminal breeds, studies have suggested that crossbreeding terminal breeds with Whiteface ewes has been profitable.

Sidwell and Miller (1971) studied growth characteristics in lambs from Hampshire, Columbia, Targhee, Suffolk and Dorset breeds of sheep and 20 various crosses among these breeds. Fourteen out of 20 crosses showed some degree of increased weaning weight due to heterosis. The highest heterosis levels were 14% for Columbia x Suffolk, Dorset x Targhee and Targhee x Hampshire lambs. The average heterosis in all crosses was 5%. Vesely and Peters (1974) studied lamb growth rates of Columbias, Suffolks, Cheviots and their crosses. Two-breed and three-breed cross lambs showed 7 and 11% heterosis, respectively, in growth rates to market weight. Baker et al. (1987) found that Coopworth and Border Leicester-sired lambs were 4 to 5% heavier at weaning than straightbred Romney lambs.

Wiener and Hayter (1975) compared weaning weights of purebred Blackface (B), Cheviot (C), and Welsh (W) lambs and crossbred lambs of B x C, B x W and C x W genotypes. Crossbred lambs were 2.9 to 3.6 Kg heavier ( $P < .05$ ) at weaning than purebred lambs. Nitter (1978), in a review, reported an average of 5% individual heterosis and 7% maternal heterosis for lamb weaning weight. The author suggested that the 5% individual heterosis in weaning weight is a recovery from individual inbreeding depression frequently found for body weight in sheep, whereas the maternal heterosis stems from uterine and postnatal conditions, which are apparently more favorable in crossbred than in purebred ewes.

Fogarty et al. (1984) compared weaning weight of purebred and crossbred lambs involving Finnsheep, Rambouillet, Dorset, Suffolk and

Targhee breeds. Heterosis for weaning weight ranged from -1 to 3%. Long et al. (1989) found 3% individual heterosis and 5% maternal heterosis for 90 day weaning weight in a study of crossing the Suffolk and Targhee breeds.

In contrast, Bradley et al. (1972) reported no heterosis in weaning weight of crossbred lambs from Suffolk and Targhee breeds and Rastogi et al. (1975) also found no heterosis for weaning weight when studying single cross lambs of the Columbia, Suffolk and Targhee breeds.

All the studies reviewed above indicated relatively low heterosis for weaning weight. While most sheep crossbreeding studies have demonstrated increased litter size through increased fertility and improved prenatal and postnatal viability of lambs, increased litter size has a negative effect on individual weaning weight (Bradford, 1972b). The low heterosis values for weaning weight may be explained by the fact that crossbred ewes tend to suckle a larger number of lambs to weaning than purebreds; therefore, superior growth potential of the crossbred lambs and greater milk production of the crossbred ewes is offset by the more competitive nursing environment (Forgarty et al., 1984).

### ***Wool Production:***

Crossbreeding has been used primarily to increase reproductive and growth efficiency in sheep. Most of the reports of crossbreeding effects on wool production were obtained from crossbred sheep produced for increased lamb production. Since coarse wool has a higher fiber diameter and hence is heavier than fine wool, increases in wool weight through crossing fine and coarse wool breeds may be due to increases in fiber

diameter and may adversely affect wool quality. The contribution of wool production to overall sheep productivity depends on the quality and quantity of wool produced and the relative economic importance of wool versus meat. In New Zealand and Australia wool growth is a key production parameter, whereas in the U.S, Finland and many other countries the quantity and quality of wool are considered of secondary importance.

A great deal of variation in wool production exists between sheep breeds. For instance, Maijala and Osterberg (1977) reported that the greasy wool yield of Finnsheep in Finland was about 2.7 kg while Fahmy et al. (1980) reported mean grease fleece weights for DLS and Nfld breeds of 3.07 and 2.40 kg, respectively. Among fine wool breeds, Ercanbrack and Knight (1985) reported mean grease fleece weights of 4.05, 4.73 and 5.29 kg for Rambouillet, Targhee and Columbia ewes, respectively.

A number of studies have reported that crossbred ewes produce more wool than purebreds, but the effect of crossbreeding on wool quality was not investigated in all studies. Sidwell and Miller (1971) compared fleece production from yearling ewes of the Hampshire, Suffolk, Dorset and Targhee breeds and a variety of crosses. Compared with the mean wool production of their purebred parents, Hampshire x Columbia cross ewes showed a 27% increase in fleece weight while Suffolk x Targhee cross showed a slight decrease. The other crosses showed 2 to 13% heterosis.

Oltanecu and Boylan (1981) reported average grease fleece weights of 2.13, 2.90, 2.67 and 4.37 kg for ewes (averaged over 1 to 3 years of age) of the Finnsheep, Minnesota 100, Suffolk and Targhee breeds, respectively. F1 Finn cross ewes with the US breeds averaged 2.93 kg, or 7% more than their parental average.

Clarke et al. (1982) reported that F1 ewes (between 2 and 4 years old) from reciprocal crosses of the Romney, Border Leicester, Cheviot and Merino breeds produced 6 to 7% more wool than purebred ewes.

Baker et al. (1987) reported data from ewes sired by Border Leicester, Coopworth and Romney rams from different sources. All ewes were from Romney dams. The mean greasy fleece weight of ewes (averaged over 2 to 5 years of age) was 4.36, 4.80 and 4.90 kg for Romney, Border Leicester and Coopworth-sired ewes, respectively. Border Leicester and Coopworth-sired ewes were superior to Romney ewes by 10 and 12%, respectively.

Meyer et al. (1977) reported that Finnsheep (F), Romney (R), East Friesian (E), F x R and E x R hogget fleece weights averaged 2.9, 3.6, 3.5, 3.0 and 3.2 kg, respectively. Fleece weights of exotic half breeds were slightly higher than exotic purebreds but were much less than straightbred Romneys.

Thomas and Whiteman (1979) compared grease fleece weights of four crossbred ewe groups of Dorset (D), Rambouillet (R) and Finn (F) breeding. The mean grease fleece weights of 1/2D:1/2R; 1/4D:3/4R; 1/4F:1/2D:1/4R and 1/4F: 1/4D:1/2R ewes (averaged over 1 to 3 year of age) were 3.95, 4.12, 3.44 and 4.00 kg, respectively. The effects of 1/4 Finnsheep (comparison of the 1/4 Finnsheep ewes with 0 Finnsheep ewes) and 1/4 Dorset (comparison of 1/2 Dorset ewes with 1/4 Dorset ewes) both resulted in significant decreases in grease fleece weight. Quality of resulting wool was also reduced.

Cochran et al. (1984) found no difference in wool weights of Dorset, 1/4Finn:3/4Dorset and 1/2Finn:1/2Dorset ewes (2.52, 2.73 and 2.65 kg,

respectively). Hulet et al. (1984) reported mean grease fleece weights of 4.18, 3.74, 3.03 and 3.37 for Targhee, inter se mated Dorset x Targhee, inter se mated Finn x Rambouillet and Polypay ewes, respectively. In addition to being 11 to 38% heavier than the other genotypes, Targhees fleeces were also finer ( $P < .01$ ).

Numerous environmental factors such as age of ewe, litter size, and season also affect wool production. Magid et al. (1981) reported wool production among Finn and Border Leicester ewes (3.3 and 3.6 kg, respectively) as sire breeds and Hampshire, Rambouillet, Targhee and 1/2 Finn ewes (3.8, 3.4, 3.6, 3.0 kg, respectively) as dam breeds. Among two age groups, the 3 year old ewes were heavier and had .42 kg higher grease fleeces and .62 kg higher clean fleeces than 2 year old ewes.

Black (1982) reported that average wool production from single, twin and triplet rearing ewes of the Coopworth breed was 6.1, 5.9 and 5.8 kg, respectively. Similar results were obtained when Rohloff and Hinch (1984) looked at the effects of litter size on wool production in a commercial flock of Coopworth ewes in the South Island of New Zealand. Total greasy wool produced per ewe per annum was 6.17 kg. Compared with ewes rearing singles, greasy fleece weight was reduced by .2 and .3 kg for ewes rearing two and three lambs, respectively, ( $P < .01$ ).

Sumner and McCall (1989) examined the clean fleece weight of sheep rearing no lambs, 1 lamb or 2 lambs. Ewes were shorn in December (weaning) and May (early gestation). Relative mean clean fleece weights of ewes shorn in December, were 100, 86 and 77 for ewes rearing 0, 1 or 2 lambs, respectively. Clean fleece weight in May was not significantly different between the rearing status groups. Cameron et al. (1983)

computed fleece production of Border Leicester (BL), Bluefaced Leicester (BFL) and Damline (DL)-sired ewes. Fleece weights of the 3 crosses were similar. The one-year-old ewes had somewhat heavier fleeces (+.15 kg) than older ewes, and the BFL and DL crosses which lambed had lighter fleeces (-0.16 kg) than barren ewes, however none of the differences were significant.

The above review suggests some increase in wool weights may result from crossbreeding, but the results depend on the breeds involved in the cross. The interaction between litter size and fleece weight further complicates the picture and makes generalization difficult and probably rather meaningless.

#### ***Composite Sheep Performance:***

Generally, high ovulation rate improves conception rate and litter size. Number of lambs weaned is a function of both number of lambs born alive and survivability of lambs born. Litter weight is a product of litter size weaned and growth rate, and largely determines the overall productivity of the ewe.

This review clearly suggests that systematic crossbreeding, introduction of germ plasm of highly prolific breeds to relatively lowly prolific breeds and development of synthetic lines (new breeds) by combining appropriate breeds, have resulted in substantial increases in sheep production potential. In order to evaluate the performance of existing and new breeds, the focus should be on composite reproductive performance, the total weight of lamb weaned per ewe exposed at all ages, rather than comparing specific components.

Unfortunately, not all components of composite production are reported in each study, nor are uniform systems used to credit multiple rearing. Nevertheless, numerous research studies have suggested substantial overall advantages from using crossbreeding.

Because the component traits have cumulative influence, the advantages of crossbreeding are most pronounced when considering the total weight of lamb weaned per ewe exposed. For instance, when growth rate of lambs to market weight was considered, in a comparison of the Columbia, Suffolk and Cheviot breeds and their crosses, the superiority of two-breed and three-breed cross lambs over purebred lambs was 7 and 11%, respectively, (Vesely and Peters, 1974). When the total weight of lamb at market per ewe bred was compared, the superiority in production of two-breed and three-breed crosses over the production of purebred lambs was increased to 17 and 33%, respectively.

Nitter (1978), in a review based on the results of many crossbreeding comparisons, has shown substantial cumulative advantages of crossbreeding in sheep. He estimated 18% individual heterosis and an additional 18% maternal heterosis in total weight of lamb weaned per ewe exposed, a product of fertility, prolificacy, lamb survival and individual weaning weight. Almost half of the individual heterosis for aggregate performance was due to improved lamb survival, a quarter to improved weaning weight and another quarter to improved levels of both prolificacy and fertility. Maternal heterosis in total weight of lamb reared per ewe exposed was mainly due to improved fertility and, to a lesser extent, to increased weaning weight of lambs.

Fahmy (1982) compared litter weight at weaning from mature ewes

representing Oxford, Suffolk, Oxford x Suffolk, Suffolk x Oxford, Cheviot x Oxford and Cheviot x Suffolk genotypes. Overall litter weaning weight from crossbred ewes was 17% higher than purebred litter weight. Suffolk and Oxford reciprocal crosses showed 18% heterosis in litter weight. Oxford crossbred ewes produced 36% heavier litters than pure Oxford ewes. The comparable superiority of Suffolk crossbreds was 4%.

Cameron et al. (1983) looked at the performance of crossbred ewes, sired by Border Leicester (BL), Bluefaced Leicester (BFL) and Damline (DL) sires, over 3 years. The dams of the crossbred ewes were hill breeds (Scottish Blackfaced, Swaledale and Welsh Mountain). Although the DL cross ewes had higher conception rate (.78 vs .73 for BFL and .62 for BL) and litter size (1.79 vs 1.63 for BFL and 1.53 for BL), they had no net advantage over BFL cross ewes because of lower lamb survival (74% vs 79% for BFL and 77% for BL) and lighter lamb weaning weights (30.2 kg vs 32.5 kg for BFL and 28.8 kg for BL). Long et al. (1989) reported 14% individual heterosis and 10% maternal heterosis in ewe productivity of Suffolks, Targhees and their crosses. Ewe productivity was defined as the weight of lamb weaned per ewe exposed to breeding per year and was determined by its component traits, i.e. conception rate, litter size, lamb survival to weaning and lamb weaning weight.

Thomas and Whiteman (1979) reported that the inclusion of 1/4 Finnsheep in crosses with the Rambouillet and Dorset breeds resulted in an increase of 3.5 kg of lamb weaned per ewe exposed as yearlings ( $P < .10$ ). The increase was primarily due to 24% higher litter size in 1/4 Finnsheep ewes than in pure Dorset or Rambouillet ewes ( $P < .01$ ). When compared at 2 and 3 years of age, the 1/4 Finnsheep effect resulted in little



improvement in weaning weight of lamb weaned per ewe exposed.

Magid et al. (1981) compared Border Leicester and Finn-sired ewes produced from Hampshire, Rambouillet, Targhee and 1/2 Finn dams. Lambs from Finn-sired ewes were 2.1 kg heavier at weaning than lambs from Border Leicester sired-ewes. The total weight of lamb weaned per ewe was 3.6 kg greater for Finn-sired ewes partly due to their higher conception rate (86 vs 78%).

Oltenacu and Boylan (1981) compared overall performance of purebred Finnsheep, US breeds (Suffolk, Targhee, Minnesota 100), and F1 and F2 Finn cross ewes. When compared at one or two years of age, total weight of lamb weaned per ewe mated averaged 29.1 vs 14.0 kg for Finnsheep and US breeds, respectively. The comparable values for F1 and F2 ewes were 21.7 and 17.8 kg, respectively. In overall productivity, F1 ewes were 55 and 22% superior to the means of the US breeds and F2 ewes, respectively.

Cochran et al. (1984) compared overall performance of Dorset, 1/4 Finn:3/4 Dorset and 1/2 Finn:1/2 Dorset ewes; respective weaning weights per ewe exposed averaged 29.4, 36.3 and 39.3 kg. In terms of dollars, the results indicated that the use of 1/4 and 1/2 Finn ewes increased total income by 15 and 30%, respectively, over that obtained from pure Dorset ewes.

Hulet et al. (1984) compared weaning weight per ewe exposed for Targhee, Dorset-Targhee, Finn-Rambouillet and Polypay ewes in summer and winter lambing. In summer lambing, Polypay ewes were 44, 53 and 85% superior to Dorset-Targhee, Finn-Rambouillet and Targhee ewes, respectively. In winter lambing Polypay ewes were 8 and 6% better than Dorset-Targhee and Finn-Rambouillet, respectively, and only slightly

better than Targhee ewes. The results suggested that Polypay sheep have relatively high potential for breeding out of season and consequently increasing overall productivity.

Fahmy and Dufour (1988) compared total weight of lambs weaned per ewe mated for the DLS and Finnsheep breeds and their seven combinations ranging from 1/8 to 7/8 Finnsheep breeding. Total weights of lamb weaned per ewe mated were 18 and 26 kg for the DLS and Finnsheep breeds, respectively. The weights for 1/8 and 7/8 Finnsheep were 22.3 and 25.5 kg, respectively. The highest weight was 28 kg for 1/2 Finn:1/2 DLS genotypes. Generally, the increase in the proportion of Finn genes in crossbred ewes results in an increase in litter size, but that advantage was offset by higher preweaning lamb mortality (10% for 1/2 Finn vs 17% for 3/4 and 7/8 Finn ewes).

Lewis and Burfening (1988) compared litter weaning weight per ewe exposed for lambs of Whiteface (Columbia, Rambouillet, Targhee) and 1/4 Finn ewes. The crossbred ewes were produced by mating Finn x Rambouillet rams to Whiteface ewes. Litter weight at weaning for 1/4 Finn ewes was 14% heavier than for Whiteface ewes ( $P < .01$ ). The difference was largely a function of higher litter size at weaning (.21 lambs) for the 1/4 Finn ewes.

Fogarty et al. (1984) compared total weight of lambs weaned per ewe for Finnsheep (F), Rambouillet (R), Dorset (D), Suffolk (S), Targhee (T), Finn-crosses (F x R, F x D, F x S, F x T) and two synthetic lines, C1(1/2F:1/4R: 1/4D) and C2(1/2F:1/4S:1/4T). Considering lambs raised by their dams, heterosis for total weight weaned per ewe exposed ranged from 39 to 48% for Finn crosses. Heterosis for total weight weaned per ewe

exposed was 43% in the C1 3 breed cross and 35% in the first intermated generation. The comparable values for the C2 composite were 51 and 37%, respectively. The small decline in performance with intermating within the synthetic crosses suggests that loss due to recombination effects was relatively unimportant. Thus, it may be feasible to develop synthetic dam lines to utilize both breed combinations and heterosis for commercial lamb production, thereby avoiding the expense of maintaining purebred lines for continual production of F1 ewes (Dickerson, 1973).

**LAMB PRODUCTION FROM POLYPAY, COOPWORTH AND CROSSBRED EWES****CHAPTER 2****Abstract**

Six ewe genotypes, generated by mating Coopworth (C), Polypay (P) and Suffolk (S) rams to Polypay and Coopworth-type ewes, were exposed to Hampshire rams for spring lambing from 1986 through 1990. Data from 1092 exposures and 1044 resultant lambing were used to analyze reproductive traits and lamb growth rates. Overall conception rate averaged 95% and ranged from 93% for S X C ewes to 97% for P X C ewes. Mean litter size at birth averaged 1.63 and ranged from 1.45 for C ewes to 1.75 for S X P ewes. Heterosis estimates were less than 2% for both conception rate and litter size. Ewes from Polypay dams had higher mean litter size ( $P < .01$ ) than those from Coopworth dams (1.73 vs 1.54), but differences between sire breeds were not significant. Incidence of lambing assistance was similar for ewes producing single or multiple lambs. Lamb birth weight influenced the level of assistance rendered to single-bearers but not to multiple-bearing ewes. Lambing assistance was not related to lamb survival, probably because the high surveillance level minimized trauma before assistance was rendered. Incidence of required assistance declined over subsequent parities. Lamb birth weights were affected by ewe genotype, and increased with increasing ewe age. Survival of single born lambs averaged 94% and was not affected by dam genotype. Survival of twins averaged 85%, ranging from 79% for lambs from S X C ewes to 89% for lambs from P ewes. Suffolk-sired ewes produced the heaviest mean birth

and weaning weights for both singles and twins. Coopworth-sired ewes weaned heavier single lambs but lighter twins than Polypay-sired ewes. Maternal heterosis for adjusted 90 day weaning weight was less than 5% for both singles and twins.

### Introduction

Efficiency of meat production in sheep would be improved by increasing litter size weaned per ewe and/or weaning weight of lambs. Such advances could be achieved by improvements in conception rate, litter size at birth, lamb survival to weaning or lamb growth rate. In the 1970's, crossbreeding was used to combine these traits in the formation of new synthetic maternal breeds. Two prominent results were the Polypay breed developed in the US from equal contributions of the Targhee, Rambouillet, Dorset and Finn breeds (Hulet et al., 1984) and the Coopworth breed developed in New Zealand from crossing Border Leicester rams with Romney ewes. Both breeds were developed primarily for production under grazing conditions, and both have experienced growing popularity in the Pacific Northwest.

The present study was designed to compare lamb production merit of Polypay and newly available Coopworth genetic material. Suffolk sires were also used to produce daughters to include comparison with this very popular breed used widely in producing crossbred ewes.

## Materials and Methods

**Animal management.** Six genotypes were produced by mating Polypay (P) ewes and Coopworth (C)-type ewes (generated by 2-3 generations of backcrossing commercial medium wool white face ewes to a sample of previously imported Coopworth rams) to purebred Polypay, Suffolk (S) and newly imported Coopworth rams. Ewes were generated in two consecutive years using three rams from each sire breed. The resulting F1 ewes were first exposed to rams at an average age of 18 months and five lamb crops were produced from 1986 through 1990. Each year ewes were group-mated on pasture for an average of 6 weeks to harnessed Hampshire rams from a resident closed breeding flock. Mating was consistently initiated in the third week of August following exposure of ewes to teaser rams for two weeks. The average ram:ewe ratio was one per 50 ewes with rams periodically replaced by fresh rams.

Ewes were maintained from mating to lambing on grass-clover pasture supplemented as necessary with silage or hay conserved from pasture in late spring. Ewes were moved indoors an average of two weeks prior to lambing and penned in groups of 30 to 40 where they received ad libitum high quality hay supplemented with concentrates. Ewes were under frequent day and night surveillance at lambing and were assisted in cases of suspected lambing difficulty. Degree of assistance was recorded along with any associated malpresentation of lambs. Immediately following lambing, each ewe and her offspring were placed in individual 1.75 m<sup>2</sup> pens for an average of 24 hours then moved to group pens. Prior to grouping, lambs were weighed and individually identified, and elastrator bands were applied for docking and castration. Most ewes returned to pasture with

their lambs within 5 days of lambing depending on weather conditions. All litters of more than two lambs were reduced to two, and twin-bearers judged to have inadequate milk had the smaller lamb removed before going to pasture. Lamb survival analysis considered all removed lambs as dead. No lambs were cross fostered. Ewes with two lambs were placed on pasture providing forage at least equal to that received by ewes with single lambs. Lambs remained with their mothers on grass-clover pastures until weaning weights were taken at an average age of 90 days. Lambs received routine vaccination and parasite treatment. They received no nutritional supplementation. Despite control measures, predators (primarily coyotes) were a major cause of pre-weaning lamb losses on pasture.

Ewes were routinely treated for internal and external parasites and treated as necessary to control footrot. The ewes also received selenium-supplemented trace mineralized salt throughout the year. A full vaccination program was administered as dictated by the herd health history. Ewes were culled only for failure to produce milk or for severe udder infections; they were not culled for reproductive failure. Predation varied between years and appeared random among genotypes.

***Statistical Procedures.*** Performance traits recorded were:

CR: Conception rate (0,1)

LA: Lambing assistance rendered the ewe and malpresentation of lambs (coded on non-linear scale of 0 = unassisted, 1 = assistance rendered but retrospectively judged unnecessary and 2 to 4 representing increasing degrees of difficulty/malpresentation requiring lambing assistance)



LS: Litter size at birth (including dead or aborted lambs)  
for each ewe lambing (1,2,3)

LSW: Number of lambs weaned for each ewe lambing (0,1,2)

BWT: Birth weight (kg) of each lamb

WWT: Weaning weight (kg) of each lamb weaned

CR, LA, LS and LSW were regarded as ewe traits while BW and WWT were considered lamb traits.

The statistical model used to describe ewe traits was:

$$Y_{ijklm} = U + S_i + R_{ij} + D_k + G_l + A_{lm} + SD_{ik} + E_{ijklm}$$

$U$  = Overall mean

$S_i$  = The effect of  $i$ th sire breed ( $i = 1-3$ )

$R_{ij}$  = The effect of  $j$ th ram of  $i$ th sire breed ( $j = 1-3$ )

$D_k$  = The effect of  $k$ th dam breed ( $k = 1,2$ )

$G_l$  = The effect of  $l$ th ewe birth year ( $l = 84,85$ )

$A_{lm}$  = The effect of  $m$ th record of ewes born in  $l$ th birth year  
( $m =$

1 to 5)

$SD_{ik}$  = The effect of S x D interaction (i.e. ewe genotype)

$E_{ijklm}$  = random variation

Additional 2 and 3 way interactions were tested and dropped from the final model after being found non-significant ( $P > .50$ ). Rams nested within sire breed were considered random while all other effects were considered fixed. Therefore, effects of sire breed were tested with rams within sire breed while all other effects were tested with the residual error. LA was analyzed within litter size as an all-or-none trait, then re-analyzed with those assisted ewes judged by the assisting shepherd as having required no

assistance (Code = 1) regarded as unassisted. Both lamb sex and birth weight (mean for twins) were included as covariats in the models.

Lamb traits were analyzed using similar models. BWT was analyzed within birth rank (single vs twin) including sex as a main effect. Triplets were excluded due to small numbers and unbalanced data. WWT was analyzed within the three birth/rearing (B/R) classes, i.e. born and reared as singles (S/S), born and reared as twins (T/T) or born as twin but reared as a single (T/S), including sex as a main effect and weaning age as a covariat in the model. WWT was also analyzed in a model including B/R as a main effect. Rearing rank was defined as weaning rank with no adjustment of T/S weaning weights for time of co-twin death. The Statistical Analysis System general linear model (SAS, 1986) was used to analyze all performance traits.

## Results

**Conception rate and litter size.** Overall conception rate was high (0.95) and did not differ among genetic groups (Table 2.1). Means ranged from 0.93 for S X C ewes to 0.97 for P X C ewes (Table 2.2). Polypay and Coopworth reciprocal crossbred ewes showed little heterosis (1.6%) for conception rate. No individual sire effects were observed for conception rate among daughter progeny groups. The effects of ewe birth year and lambing year nested within ewe birth year appeared to be random and were non-significant ( $P>.24$ ). No interactions were observed between genotype, ewe birth year and lambing year nested within ewe birth year, so were deleted from the model.

Means for litter size are shown in Table 2.2. Litter size per ewe lambing averaged 1.63, ranging from 1.45 for Coopworth ewes to 1.75 for S X P ewes crosses ( $P<.05$ ). Daughters of Polypay dams had higher mean litter size than daughters of Coopworth dams ( $P<.05$ ) and straightbred Polypay ewes produced .29 more lambs per parturition than straightbred Coopworths ( $P<.05$ ). Differences among sire breeds were not significant; however, variation in litter size was observed among sires within breeds ( $P<.05$ ).

Litter size varied among ewe birth/lambing years ( $P<.01$ ) but partial confounding of age and lambing year made it impossible to clearly separate the two effects. Examination of performance within genotypes and birth years indicated that litter size was consistently lowest for two-year-olds with a substantial increase at the second lambing and marginal increases thereafter.

**Lambing assistance.** The incidence of lambing assistance rendered to ewes (26% of single-bearers and 13% multiple-bearers

assisted), was much higher than the retrospective need for assistance (5% of single-bearers and 8% of twin bearers; Table 2.2). Daughters of Coopworth sires required the most lambing assistance whether giving birth to single or multiple lambs ( $P < .05$ ) and daughters of Coopworth dams required more assistance than daughters of Polypay dams ( $P < .05$ ; Table 2.1). Among individual genotypes, Coopworth ewes required the most assistance when producing either single (16%) or multiple lambs (14%), while Polypay ewes required very little assistance in either situation. Reciprocal Polypay x Coopworth cross ewes required very little assistance when giving birth to singles but were intermediate between the parental breeds when giving birth to multiple lambs.

Amongst single lambs, males caused more lambing difficulties than did females (Table 2.2). This effect was reduced but not removed by inclusion of birth weight as a covariate in the analysis. Among single lambs, heavier birth weights increased the likelihood of assistance being rendered ( $P < .01$ ), but did not significantly affect the requirement for assistance to the dam. Among multiple lambs, birth weight had no bearing on the incidence of assistance either rendered or required.

Level of assistance required varied among lambing years ( $P < .05$ ) for both single and multiple births. This was largely due to a decline in required assistance over parities. Required assistance declined from 8% of single-bearers and 11% of multiple-bearers in the first parity to 1% and 3%, respectively, in the fourth parity.

**Birth weight.** Birth weights were analyzed separately for singles and twins and results are shown in Tables 2.1 and 2.2. The mean birth weight of singles was 5.7 kg, ranging from 5.1 kg for lambs from Polypay

ewes to 6.1 kg for lambs from S X C ewes ( $P < .05$ ). Ewes from Coopworth dams produced heavier single lambs than ewes from Polypay dams (5.9 vs 5.6 kg;  $P < .01$ ) and the same was true for daughters of Coopworth vs Polypay sires (5.9 vs 5.3 kg;  $P < .01$ ). The estimated heterosis for birth weights of single lambs from the reciprocal cross ewes was 2%.

The mean birth weight of twin born lambs was 4.4 kg with a much narrower range among genotypes than was observed for singles. Ewes of Coopworth and Polypay origin had virtually identical birth weight for twin-born lambs and no heterosis was observed. Suffolk-sired ewes produced both the heaviest singles and twins at birth ( $P < .01$ ).

Sires within breed also affected birth weights of lambs born to their daughters ( $P < .01$ ). This effect was greater among singles than twin-born lambs. Male lambs were 6% heavier than females in both single and twin birth ranks ( $P < .01$ ) while both male and female singles averaged 30% heavier birth weights than corresponding twins. Both ewe birth year and lambing year within birth year affected birth weights ( $P < .01$ ).

***Lamb survival to weaning.*** Since litter size is confounded with survival, ability to rear lambs was assessed as a ewe trait by analyzing litter size at weaning separately for single and twin-lambing ewes (Table 2.3). Mean litter size at weaning for single-bearing ewes was .94 and did not differ among ewe genotypes (Table 2.4). Single male lambs had 5% higher survival (.97 vs .92) than single females ( $P = .06$ ).

Mean litter size at weaning for twin-born lambs was 1.69, indicating that individual lamb survival for twins was 10% below that for singles. Ewe sire breed did not effect lamb survival, but twin-bearing ewes from Polypay dams weaned .1 more lambs than did twin-bearing ewes from

Coopworth dams ( $P < .05$ ). Straightbred Polypay and Coopworth ewes did not differ in success of rearing single lambs, but twin-producing Polypay ewes weaned .1 more lambs than twinning Coopworths. Heterosis estimates for litter size at weaning among P X C reciprocal cross ewes were slightly negative among both single and twin-producing ewes.

Twinning ewes producing heavier total birth weight of lambs exhibited higher litter size at weaning ( $P < .01$ ; Table 2.3). Ewes producing same sex twins had higher litter size at weaning than those producing mixed sex twins (1.72 vs 1.63). Twin males and females had equal survival when born in same-sex litters; however, males had slightly higher survival than their sisters when born in mixed-sex litters.

**Weaning weight.** Weaning weight analyses and means are shown in Tables 2.3 and 2.4. Weaning weights differed among B/R classes ( $P < .01$ ) with S/S lambs averaging 35% heavier than T/T lambs and 23% heavier than T/S lambs. Suffolk-sired ewes produced the heaviest lambs in all three B/R classes ( $P < .05$ ), their lambs averaging 8% heavier than lambs from ewes without Suffolk genes. Ewes from Coopworth sires produced slightly heavier S/S lambs but lighter T/S and T/T lambs than ewes from Polypay sires. The same pattern was true for ewes from Coopworth vs Polypay dams. Accordingly, compared to straightbred Polypay ewes, straightbred Coopworth ewes produced S/S lambs that were 5% heavier, but their T/T lambs were 5% lighter. B/R heterosis estimates from lambs of reciprocal cross ewes were 2% (S/S), 6% (T/S) and 3% (T/T).

Both ewe birth year and lambing year influenced weaning weights in all B/R classes ( $P < .01$ ). Ewes weaned the lightest lambs at their first parity, particularly if they were rearing twins. The largest increase

occurred between first and second parities with a smaller increase the following year. Weaning weights of males were consistently 4 to 5% heavier than females in all B/R classes ( $P < .01$ ).

## Discussion

The biggest effect of Polypay vs Coopworth genes on ewe productivity occurred in litter size. Daughters of Coopworth and Polypay rams exhibited comparable litter size; however, daughters of Coopworth-type ewes had lower litter size than daughters of Polypay ewes. This difference is probably due to source of breeding stock. Rams of both breeds were of high expected genetic merit and from prominent flocks within their respective breeds. Polypay ewes likewise were derived directly from foundation flocks; however, the only available source of Coopworth-type ewes was a flock in which an earlier importation of Coopworth rams had been used for 2-3 generations to upgrade commercial medium wool ewes. Thus, the daughters of Coopworth sires may more accurately reflect the genetic merit of the breed than do daughters of Coopworth-type dams.

The pattern of birth weights, survival and weaning weight of lambs from P and C-derived ewes suggests that P genes may allow ewes to respond better to the challenge of producing and rearing twin lambs. Trial site pasture weather conditions after lambing often include extended periods of cold, wet weather with periodic frosts and occasional snow. Forage availability following lambing is dependent on retention of the previous autumn's pasture growth, and little new growth may occur for the first several weeks of lactation. This can be a period of considerable stress on both ewes and lambs and draw heavily on ewes' body reserves. Twin lambs from ewes of the two breed origins were the same weight at birth, but those from P-derived ewes both survived better and grew faster to weaning. While Finn genes have been shown to increase lamb survival



(Smith, 1977; Oltenacu and Boylan, 1981; Lewis and Burfening, 1988) especially in crosses with blackface breeds (Dickerson et al, 1975), it seems unlikely that the low level of Finn breeding in crossbred lambs from Polypay-derived ewes would account for the difference. The superior growth of twin lambs from P-derived ewes suggests that such ewes have superior maternal ability, probably expressed via higher milk production.

Although pre-lambing body condition was not assessed in this trial, previous experience with Coopworth and Polypay sheep (Meyer, unpublished data) indicates that Polypay ewes maintain a higher level of body condition when both are grazed together under sub-optimal feed conditions. Accordingly, Polypay-derived ewes may have had greater fat reserves to mobilize at lambing. Increased milk production would also support the observed higher lamb survival to weaning, both because any initial lamb removal before ewes went to pasture was due to a subjective assessment of adequacy of milk production, and because the primary causes of death among twin-born lambs under pasture conditions tend to be starvation-related (Hight and Jury, 1970). The suggestion that twinning leads to a greater milk response in P than in C-derived ewes is also supported by the weaning weights of lambs born as twins but reared as singles (i.e. T/S lambs). Starting from virtually identical birth weights, T/S lambs from P-derived ewes averaged 14% heavier at weaning than those from C-derived ewes.

Single lambs from P-derived ewes were lighter at birth but survived and grew at the same rate as ewes from C-derived ewes. Since the comparable birth weight patterns of twins suggest that P and C genes have similar effect on adequacy of the uterine environment, the lighter birth

weight of P-derived singles may be a direct genetic effect of Finn genes which have been shown to produce lambs of lighter birth weight when  $\frac{1}{4}$  Finn ewes are mated to Blackface sires as was done in this trial (Cochran et al., 1984; Lewis and Burfening, 1988). The comparable growth in S/S lambs from C and P-derived ewes suggests no superiority of milk production for P-derived ewes following birth of a single lamb. The modest weaning weights of all lambs under the conditions of this trial suggest that the effect of early stresses were not overcome before weaning. However, post-weaning growth studies with these lambs have shown no lasting impairment to growth, at least to slaughter weights (Arnold and Meyer, 1988).

Under forage-based production systems such as applied to this trial, attention at lambing is often the major labor input. Accordingly, the level of lambing assistance required by ewes is important, particularly if ewes lamb on pasture with minimum attention. While the Coopworth breed was developed with selection emphasis on ease of lambing, C-derived ewes both received more lambing assistance and were judged to have required more lambing assistance than P-derived ewes. It is not known whether length of parturition differs between these genotypes, but it may be relevant that among the six genotypes, Coopworth ewes produced the heaviest lambs relative to ewe body weight while Polypays produced the lightest. Under the management conditions of this trial where student shepherds were often keeping close surveillance, the incidence of rendered vs required assistance was probably quite high. This is apparent from the fact that while 26% of single-bearing ewes were assisted, only 5% were judged after the fact to have required assistance. Even this estimate may be inflated because all lambs with other than normal presentation were

judged to require assistance. Length of delivery is a major factor influencing rendering of assistance, and may explain why birth weight of singles had a major effect on incidence of assistance rendered but not on assistance required. Likewise single males with their heavier birth weights attracted considerably more lambing assistance but were judged to require only slightly more assistance than females.

Multiple-bearing ewes received only half the assistance of single-bearers (13% vs 26%) but were judged to require more (8% vs 5%). The majority of assisted multiple births were malpresentations, and thereby classified as requiring assistance.

Assistance of ewes at lambing was not found to be related to lamb survival. This is in contrast to common observations that difficult births result in reduced lamb survival and growth. The prompt and possible premature attention given ewes in this study may have resulted in a minimum of trauma to both ewes and lambs so that even when assistance was truly required, it was rendered before any substantial damage occurred.

The consistent lack of heterosis observed for reproductive traits and lamb survival in the Coopworth-Polypay reciprocal crosses is atypical of previous research reports (e.g. Sidwell and Miller, 1971; Nitter, 1978; Fogarty et al., 1984) and may reflect the high degree of heterozygosity already expected to exist within these two newly-formed synthetic breeds.

The high relative litter size observed for Suffolk cross ewes was somewhat unexpected. While Suffolk cross flocks are often quite prolific (e.g. Meyer and Lewis, 1989), the source flock of rams used did not have a history of high reproductive output under the grazing conditions of this

trial. The observed prolificacy of S X P and S X C ewes may be a reflection of heterosis as reported by Sidwell and Miller (1971) from crosses of Suffolks with four other breeds. The heavier birth and weaning weights of lambs from Suffolk cross ewes is typical (e.g. Dickerson et al., 1975) and is probably influenced by the breed's large mature size since breeds tend to rank similarly on birth weight and on mature weight (Donald and Russell, 1970). The good lamb survival and growth of lambs from Suffolk cross ewes may also be a result of higher relative milk production of the Suffolk breed as reported by Snowden and Glimp (1991).

The considerable variation observed in reproductive traits and weaning weights over years appeared due primarily to ewe age and long-lasting environmental effects. A serious abortion problem among Coopworth-type ewes in the first year of generating experimental animals led to low net numbers of lambs produced. Accordingly, the same rams were reused for generating females the second year. Poor growth of the first year class resulted in ewes of smaller mature size. While this did not adversely affect either their conception rate or litter size, ewes of the first year class produced lambs of lighter birth and weaning weights throughout their lives. With a few exceptions, ewes of both year classes produced lambs of increasingly heavier birth and weaning weights with successive parities. The effect of ewe age on birth weights tended to be curvilinear as previously reported by Hight and Jury (1970), Dickerson et al. (1975) and Lewis and Burfening (1988). The combination of increasing weaning weights and higher litter sizes resulted in a 28% increase in lamb weight weaned per ewe between first and subsequent lambings (Nawaz, et al., 1991).

The only trait showing year effects unrelated to ewe age appeared to be survival of twin lambs. This was probably a reflection of weather conditions during February when most ewes and lambs went to pasture, and would explain the strong influence of birth weight on survival of twins. Conversely, birth weight had no effect on survival of single-born lambs, either within or between sexes. This may be due to the very high overall survival of single-born lambs in this study.

The high observed survival of male lambs relative to females is contrary to virtually all previous reports (e.g. Hight and Jury, 1970; Dickerson et al., 1975; Smith, 1977; Oltenacu and Boylan, 1981). The high level of care at parturition may have reduced dystocia trauma, a primary cause of death in single males, while twin males may have benefitted from their higher mean birth weights to help ward off the starvation/exposure stresses strongly instrumental in causing losses of multiple-born lambs. The latter situation might also explain the higher survival of males in mixed-sex twins.

### Implications

Results of this trial indicate that under pasture conditions Coopworth-derived ewes are less prolific than Polypay-derived ewes and wean lambs of lower body weight. They also exhibit more apparent lambing difficulty although it is not known to what extent this would affect lamb survival. Suffolk and Coopworth-sired ewes appear to be very similar in fertility and lamb survival but Suffolk-sired ewes wean heavier lambs. Under farm flock conditions it appears that Coopworth-derived ewes are inferior to the other two breeds for annual weight of lamb produced per ewe mated and that they do not require less attention at lambing despite their so-called 'easy care' emphasis during development of the breed.

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TABLE 2.1. SUMMARY OF F STATISTICS FROM ANALYSIS OF VARIANCE FOR EWE REPRODUCTIVE TRAITS AND LAMB BIRTH WEIGHTS

Source	df	Conception	Litter	Assistance		Birth weight	
		rate	size	Singles	Multiples	Singles	Twins
Sire Breed (SB)	2	1.50	1.55	4.41*	3.37*	3.77*	11.19**
Dam breed (DB)	1	.24	29.64**	5.23*	3.81*	12.06**	.23
SB X DB	2	.29	.59	3.66*	.37	.49	.90
Ram/SB	6	1.30	2.12*	1.02	.21	8.12**	2.57*
Ewe birth year (EBY)	1	3.01*	1.28	.09	1.57	.42	20.31**
Year/EBY	7	1.32	4.50**	2.26*	2.64*	13.37**	43.14**
Sex	1			1.78		20.42**	37.88**
Residual mean square		.42	.27	.22	.05	.60	0.52
(Residual df)		(1,072)	(1,024)	(365)	(626)	(369)	(1,213)

\*\*P<.01, \*P<.05, +P<.10.

TABLE 2.2. LEAST SQUARE MEANS FOR EWE REPRODUCTIVE TRAITS, PROPORTION OF EWES ASSISTED AT LAMBING AND INDIVIDUAL LAMB BIRTH WEIGHTS

	Ewes lambing									
	Conception rate		Litter size		Assisted		Birth weight (kg)			
	No.	Mean	No.	Mean	Singles	Multiples	No.	Singles	No.	Twins
Sire breed:										
Coopworth (C)	332	.95	320	1.57	.09 <sup>a</sup>	.11 <sup>a</sup>	137	5.87 <sup>b</sup>	343	4.26 <sup>b</sup>
Polypay (P)	382	.97	370	1.64	.02 <sup>b</sup>	.04 <sup>b</sup>	136	5.28 <sup>c</sup>	446	4.30 <sup>b</sup>
Suffolk (S)	378	.94	354	1.68	.02 <sup>b</sup>	.07 <sup>ab</sup>	117	5.98 <sup>a</sup>	445	4.62 <sup>a</sup>
Dam breed:										
Coopworth	390	.95	372	1.54 <sup>a</sup>	.07 <sup>a</sup>	.10	175	5.85 <sup>a</sup>	377	4.38
Polypay	702	.95	672	1.73 <sup>b</sup>	.02 <sup>b</sup>	.06	215	5.57 <sup>b</sup>	857	4.40
Ewe genotype:										
C X C	99	.94	94	1.45 <sup>c</sup>	.16 <sup>a</sup>	.14 <sup>a</sup>	52	5.96 <sup>ab</sup>	81	4.22 <sup>b</sup>
P X P	236	.96	228	1.74 <sup>a</sup>	.03 <sup>b</sup>	.02 <sup>b</sup>	70	5.10 <sup>c</sup>	298	4.27 <sup>b</sup>
P X C	146	.97	142	1.55 <sup>bc</sup>	.01 <sup>b</sup>	.07 <sup>ab</sup>	66	5.45 <sup>b</sup>	148	4.30 <sup>b</sup>
C X P	233	.96	226	1.69 <sup>ab</sup>	.03 <sup>b</sup>	.09 <sup>ab</sup>	85	5.79 <sup>b</sup>	262	4.33 <sup>b</sup>
S X C	145	.93	136	1.61 <sup>ab</sup>	.05 <sup>b</sup>	.08 <sup>ab</sup>	57	6.14 <sup>a</sup>	148	4.60 <sup>a</sup>
S X P	233	.94	218	1.75 <sup>a</sup>	.01 <sup>b</sup>	.06 <sup>ab</sup>	60	5.83 <sup>ab</sup>	297	4.64 <sup>a</sup>
Sex:										
Female					.03		195	5.53 <sup>b</sup>	626	4.27 <sup>b</sup>
Male					.06		195	5.89 <sup>a</sup>	608	4.52 <sup>a</sup>
Overall	1,092	.95	1,044	1.63	.05	.08	390	5.71	1,234	4.40

<sup>a,b,c</sup>Means in the same column within categories without common letters in their superscripts differ ( $P < .05$ ).

TABLE 2.3. SUMMARY OF F STATISTICS FROM ANALYSIS OF VARIANCE FOR LITTER SIZE AT WEANING AND WEANING WEIGHTS WITHIN BIRTH/REARING RANKS

Source	df	Litter size		Individual weaning weights (kg)		
		Single	Twin	S/S <sup>a</sup>	T/S	T/T
Sire Breed (SB)	2	.03	.58	3.68 <sup>+</sup>	3.83 <sup>+</sup>	7.42 <sup>**</sup>
Dam Breed (DB)	1	.55	3.69 <sup>*</sup>	4.64 <sup>*</sup>	6.45 <sup>**</sup>	.64
SB X DB	2	.45	1.11	.84	.63	3.99 <sup>*</sup>
Ram/SB	6	2.10 <sup>*</sup>	1.31	2.30 <sup>*</sup>	1.30	3.24 <sup>**</sup>
Ewe Birth Year (EBY)	1	.02	.23	7.82 <sup>**</sup>	8.25 <sup>**</sup>	13.19 <sup>*</sup>
Year/EBY	7	1.13	1.94 <sup>*</sup>	22.38 <sup>**</sup>	5.98 <sup>*</sup>	71.09 <sup>**</sup>
Birth Weight	1	.01	30.09 <sup>**</sup>			
Sex	1	3.38 <sup>+</sup>	1.84	7.71 <sup>**</sup>	1.30	31.89 <sup>**</sup>
Weaning Age	1			103.50 <sup>**</sup>	20.39 <sup>**</sup>	78.62 <sup>**</sup>
Residual Mean Square		.06	.29	16.76	24.75	12.38
(Residual df)		(369)	(596)	(327)	(124)	(880)

<sup>a</sup>Birth/rearing ranks: S/S = born and weaned as single; T/S = born twin, weaned as single; T/T = born and weaned as twin.

\*P<.05, \*\*P<.01, +P<.10.

TABLE 2.4. LEAST SQUARE MEANS FOR LITTER SIZE AT WEANING AND INDIVIDUAL LAMB WEANING WEIGHTS (kg) WITHIN BIRTH/REARING RANK

	Litter size				Weaning weight					
	Single birth		Twin birth		S/S <sup>a</sup>		T/S		T/T	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Sire breed:										
Coopworth (C)	137	.94	172	1.67	124	33.13 <sup>c</sup>	37	24.95 <sup>c</sup>	322	23.66 <sup>d</sup>
Polypay (P)	137	.95	224	1.73	119	32.95 <sup>c</sup>	58	28.05 <sup>b</sup>	322	25.01 <sup>c</sup>
Suffolk (S)	117	.94	223	1.67	106	35.00 <sup>b</sup>	51	29.42 <sup>b</sup>	258	25.93 <sup>b</sup>
Dam breed:										
Coopworth	175	.95	191	1.64 <sup>c</sup>	160	34.18 <sup>b</sup>	49	26.07 <sup>c</sup>	248	24.76
Polypay	216	.93	428	1.74 <sup>b</sup>	189	33.20 <sup>c</sup>	97	28.88 <sup>b</sup>	654	24.98
Ewe genotype:										
C X C	52	.96	41	1.67	48	33.37 <sup>cd</sup>	6	22.53 <sup>c</sup>	60	23.32 <sup>d</sup>
P X P	71	.95	149	1.77	60	32.05 <sup>d</sup>	36	28.90 <sup>b</sup>	226	24.59 <sup>c</sup>
P X C	66	.94	75	1.69	59	33.84 <sup>bc</sup>	22	27.20 <sup>b</sup>	96	25.42 <sup>bc</sup>
C X P	85	.92	131	1.68	76	32.87 <sup>d</sup>	31	27.37 <sup>b</sup>	198	24.00 <sup>c</sup>
S X C	57	.96	75	1.57	53	35.55 <sup>b</sup>	21	28.49 <sup>b</sup>	92	25.53 <sup>bc</sup>
S X P	60	.92	148	1.76	53	34.66 <sup>b</sup>	30	30.35 <sup>b</sup>	230	26.33 <sup>b</sup>
Sex:										
Female	196	.92	148	1.71	172	33.06 <sup>c</sup>	67	26.97	451	24.20 <sup>c</sup>
Male	195	.97	155	1.72	173	34.32 <sup>b</sup>	79	27.97	451	25.53 <sup>b</sup>
Mix			316	1.63						
Overall	391	.94	619	1.69	349	33.69	146	27.47	902	24.87

<sup>a</sup>Birth/rearing ranks: S/S = born and weaned as single; T/S = born twin, weaned as single; T/T = born and weaned as twin.

<sup>b,c,d</sup>Means in the same column within categories without common letters in their superscripts differ (P<.05).

**SURVIVAL AND CUMULATIVE LAMB AND WOOL PRODUCTION OF POLYPAY,  
COOPWORTH AND CROSSBRED EWES OVER FOUR YEARS**

**CHAPTER 3**

**Abstract**

Six ewe genotypes, generated by mating Coopworth (C), Polypay (P) and Suffolk (S) rams to Polypay and Coopworth-type ewes, were exposed to Hampshire rams for spring lambing from 1987 through 1990. Data from 1013 exposures and 973 resultant lambings were used to analyze reproductive traits and cumulative ewe productivity over 4 yr. Ewe body and fleece weights were also analyzed. Overall conception rate was high (96%) and differences among ewe genotypes were not significant. Mean litter size averaged 1.63 with ewes from Polypay dams producing .20 more lambs per litter than daughters of Coopworth-type dams. Sire breeds did not differ in the litter size of their daughters. Ewes from Suffolk sires weaned the heaviest lambs while ewes from Polypay sires weaned the largest number of lambs, resulting in similar weight of lamb weaned per ewe mated. Coopworth-sired ewes weaned the least weight of lamb. Ewes weaning twins produced 54% more total litter weight per ewe than those weaning singles. Annual ewe survival averaged 95%, ranging from 93% for S x P and C x P ewes to 97% for P x C and Coopworth ewes. When cumulative number and weight of lamb produced was assessed on the basis of all ewes starting the trial, Polypay-sired ewes were highest followed by daughters of Suffolk and Coopworth sires. Suffolk-sired ewes (67 kg) were 13% heavier than Polypay daughters and 19% heavier than Coopworth daughters. Adjustment of

lamb production for ewe metabolic body size resulted in Coopworth-sired ewes being more efficient than the heavier Suffolk-sired ewes. Coopworth-sired ewes produced 32% more wool than ewes sired by the other two breeds. Differences in wool production between ewes weaning one or two lambs were small. Comparing genotypes on the basis of an index combining lamb and wool production resulted in a range of less than 2% between sire breeds for gross productivity per ewe mated.

### Introduction

Overall productivity of any species or genotype depends upon numerous components. Studies of genetic variation in productivity of livestock typically either are limited to a few of these components or measure gross production without reference to the relative contributions made by the various components. Studies of productivity are also typically limited to measures of output without reference to variation in input parameters. In the case of meat production, output of the breeding population is dependent principally upon net reproductive rate (i.e. number) and size of progeny produced. Each of these, in turn, is dependent upon component parameters. When a species produces more than one commodity, such as meat and wool in the case of sheep, overall productivity estimates must encompass all output.

We have evaluated the productivity of a newly available genotype, Coopworth sheep, relative to other genotypes by assessing both cumulative lamb production over four lambings and contributing components related to survival, reproduction and growth. We have then attempted to examine the interactions of these components and estimate relative efficiencies by adjusting gross lamb production for ewe body size, the best indicator of nutritional requirements as they apply to lamb production under grazing conditions. Production of wool, the second product of dual purpose sheep, was also measured and related to lamb production.

## Materials and Methods

**Animal Management.** Six ewe genotypes were produced by mating Polypay and Coopworth-type ewes (generated by 2-3 generations of backcrossing commercial medium wool white face ewes to a sample of previously imported Coopworth rams) to purebred Polypay, Suffolk and Coopworth rams in two consecutive years. The Coopworth rams were from a recent importation selected from prominent New Zealand flocks. The resulting F<sub>1</sub> ewes, born in 1984 and 1985, were first exposed to rams at an average age of 18 months and five lamb crops were produced from 1986 through 1990. Results of the 1987 through 1990 lambings, when both ewe year classes were in production, were used for this study. Ewes were annually group mated on pasture to harnessed Hampshire rams for an average of 6 weeks with ewe body weights being recorded shortly before ram introduction. Three weeks prior to lambing, ewes were moved indoors where they received hay and supplemental concentrates. Immediately following lambing, each ewe and her offspring were placed in individual 1.75 m<sup>2</sup> pens for an average of 24 hours then moved to group pens. All male lambs were castrated within 48 hr of birth. All litters of more than two lambs were reduced to twins and twin-bearers judged to have inadequate milk had the smallest lamb removed before going to pasture. Ewes received no weaning weight credit for lambs removed. Additional details of mating, lambing and pre-weaning management were presented by Nawaz and Meyer (1991).

Ewes were shorn annually during the third week of May; individual fleece weights were recorded from 1988 through 1990. Ewes were culled only for severe udder infections or failure to produce milk. Ewe and lamb mortality due to predation (primarily coyotes) varied among years and appeared random among genotypes.



**Statistical Procedures.** Numerous survival and productivity parameters were estimated for each genotype. The starting group size for each genotype was taken to be the number of ewes present at lambing in 1987. Thereafter yearly survival was calculated as the number of ewes present at lambing in each year relative to the number of ewes present at lambing the previous year. Average annual survival was taken to be the arithmetic mean of the yearly survival estimates. Average conception rate was similarly estimated from number of ewes lambing in each year relative to number of ewes present at lambing.

Individual lamb weaning weights for each year were adjusted within rearing rank (single vs. twin) to a 90 day male equivalent basis. Litter weight for each ewe rearing lambs was calculated as the total adjusted weight of lamb(s) weaned. Following assignment of zero values to the year's production record of any ewe no longer present or present but failing to wean a lamb, conception rate, litter size at birth and weaning, total number and weight of lambs produced over 4 years, number of years that at least one lamb was weaned, litter weight per ewe mated, litter weight per ewe weaning lambs and annual ewe breeding and fleece weights were analyzed by using the general linear model (GLM) procedure in SAS (1986).

The final statistical model used to describe ewe traits was:

$$Y_{ijkl} = U + S_i + D_j + A_k + SD_{ij} + E_{ijkl}$$

$U$  = Overall mean

$S_i$  = The effect of  $i$ th sire breed ( $i = 1$  to  $3$ )

$D_j$  = The effect of  $k$ th dam breed ( $k = 1, 2$ )

$A_k$  = The effect of  $m$ th record ( $m = 1$  to  $4$ )

$SD_{ik}$  = The effect of  $S \times D$  interaction (i.e. ewe genotype)

$$E_{ijkl} = \text{random variation}$$

Other interactions between main effects and variation among sires within sire breed were also included in preliminary analyses but were found to explain little of the observed variation and were accordingly omitted from the final model. The standard errors for estimates of several traits were also estimated by Bootstrap techniques (Efron and Tibshirani, 1986) using 1,000 generated subsamples created by randomly sampling with replacement within each genotype. The standard errors obtained from the Bootstrap and SAS GLM procedures were virtually identical in most cases; when the two differed, Bootstrap standard errors were used for testing genotype differences.

## Results

***Ewe Survival.*** Ewe survival patterns are shown by genotype in Table 3.1. Mean annual survival was .95 with little variation observed between years (Table 3.2). Mean annual survival ranged from .93 for C X P and S X P ewes to .97 for Coopworth and P X C ewes. Dropout due to culling was low in all genotypes. The differential ewe dropout rate resulted in the proportion of initial ewes remaining at the fourth lambing ranging from .81 for C X P ewes to .92 for Coopworth ewes. Daughters of Coopworth-type dams had a mean annual survival rate of .97 resulting in 90% of initial ewes still present at the fourth lambing compared to only 83% of daughters from Polypay dams. No difference was detected among daughters of the three sire breeds. Reciprocal Coopworth X Polypay crosses demonstrated - 3% heterosis for survival through four lambings.

***Ewe ability to rear lambs.*** The proportion of lambing ewes which weaned lambs is shown by year and genotype in Table 3.1 with overall means presented in Table 3.2. Overall, 94% of lambing ewes weaned lambs. Ewes tended to be least successful at their first lambing although daughters of Suffolk sires were most successful. Among sire breeds, 95% of lambing daughters from Polypay rams weaned lambs compared to 93% and 91% of daughters from Suffolk and Coopworth sires, respectively ( $P < .05$ ). Daughters of Polypay dams were likewise more likely to successfully wean at least one lamb than daughters of Coopworth dams. Coopworth X Polypay reciprocal crosses showed 2% heterosis for incidence of weaning lambs among ewes lambing.

***Litter weight weaned per ewe weaning lambs.*** The overall mean weight of lamb weaned per ewe weaning lambs was 41 kg (Table 3.2) and ranged from 38 kg for Coopworth ewes to 45 kg for S X P ewes. Daughters of Suffolk

sires had the heaviest mean litter weight (43 kg) followed by daughters of Polypay (41 kg) and Coopworth sires (39 kg) ( $P < .05$ ). Daughters of Polypay dams likewise weaned 2 kg more lamb weight than daughters of Coopworth dams ( $P < .05$ ). Mean weight of lamb produced from ewes weaning lambs was less in the first year than in subsequent years ( $P < .01$ ). Ewes rearing twins produced 54% more weight of lamb weaned than ewes rearing singles. This advantage ranged from 44% for Coopworth to 61% for S X P ewes. Coopworth X Polypay reciprocal crosses showed 6% heterosis for total weaning weight of twin vs single litters.

***Number of productive years.*** The mean number of productive years (i.e. at least one lamb weaned) is shown in Table 3.3 for each ewe genotype. The overall mean was 3.4, ranging from 3.2 for S X P ewes to 3.6 for P X C ewes. Polypay and P X C ewes were superior to all other genotypes ( $P < .05$ ). Daughters of Polypay sires had the highest number of productive years during the trial, 3.5, compared to 3.3 for daughters of Coopworth and Suffolk sires, ( $P < .05$ ). The two dam breeds did not differ in this trait, while Coopworth X Polypay reciprocal cross ewes showed 2% heterosis.

***Cumulative number of lambs produced.*** The mean cumulative number of lambs weaned during the study per ewe present in the first year was 4.9, ranging from 4.4 for Coopworth ewes to 5.4 for Polypay ewes ( $P < .05$ ; Table 3.3). Coopworth X Polypay reciprocal crosses showed no heterosis for this measure of productivity. Ewes derived from either Polypay sires or dams weaned more total lambs during the trial than ewes from the other sire or dam breeds ( $P < .01$ ).

***Cumulative weight of lambs produced.*** Cumulative weights of lamb produced, based on pooled adjusted litter weights for each ewe present at

the start of the trial, are presented in Table 3.3 for the various genotypes. Mean cumulative weight of lamb produced was 138 kg, ranging from 124 kg for Coopworth ewes to 146 kg for Polypay ewes ( $P < .05$ ). Daughters of Polypay and Suffolk sires produced greater weight of lamb weaned than daughters of Coopworth sires ( $P < .05$ ) while daughters of Polypay dams tended to produce more lamb weight than daughters of Coopworth-type dams ( $P < .10$ ). Coopworth X Polypay reciprocal crosses showed less than 3% heterosis for cumulative weight of lamb weaned per ewe entering the flock.

**Wool Production.** Mean fleece weights of ewes rearing lambs are shown in Table 3.4 for each of the three years recorded. Overall mean wool production was 3.1 kg, ranging from 2.8 kg for S X C ewes to 3.8 kg for Coopworth ewes ( $P < .01$ ). Daughters of Coopworth sires produced more wool than daughters of Polypay or Suffolk sires ( $P < .01$ ) in every year of the trial; however, daughters of Coopworth-type dams produced no more wool than daughters of Polypay dams. Reciprocal Coopworth X Polypay crosses showed no heterosis for fleece weight. Fleece weight per ewe recorded was higher in 1988 than in the last two years of the trial ( $P < .01$ ). Ewes rearing two lambs in 1988 produced .14 kg less wool than those rearing single lambs ( $P = .07$ ). Number of lambs reared did not affect ewe fleece weight in the last two years.

**Ewe body weight.** Mean pre-mating ewe body weights are shown in Table 3.3. Overall mean weight was 61 kg ranging from 55 kg for C X P to 68 kg for S X C ewes ( $P < .01$ ). Daughters of Suffolk sires were heaviest (67 kg) followed by daughters of Polypay (59 kg) and Coopworth (56 kg) rams ( $P < .05$ ). Daughters of Coopworth-type dams were heavier than ewes from Polypay dams (62 vs 59 kg;  $P < .01$ ). No heterosis was observed for

breeding weight among Coopworth X Polypay reciprocal cross ewes.

***Lamb production relative to ewe weight.*** Mean annual weight of lamb weaned per ewe mated (Table 3.3) was calculated for each genotype then divided by the appropriate metabolic body size ( $wt^{0.75}$ ; Kleiber, 1975) to estimate productivity relative to ewe size. Polypay ewes were the most productive with annual production of 1.9 kg of lamb weaned per unit of metabolic body size. Results for other genotypes are shown relative to Polypay ewes (arbitrarily assigned a value of 100) in Table 3.3. S X C ewes were least productive, achieving only 81% of Polypay level. Among sire breeds, relative values for daughters of Polypay, Coopworth and Suffolk sires were 97, 91 and 88%, respectively. Daughters of Polypay dams had higher ratios than those from Coopworth-type dams (98 vs 86%).

## Discussion

Ewe productivity is made up of many components and thus can be defined in numerous ways. The decision whether to measure on an annual basis (e.g. weight weaned/ewe mated) or over a longer time interval (e.g. lifetime productivity) is in part dependent upon the replacement cost or depreciation rate of ewes. Likewise the desirability of adjusting output for input costs is dependent upon the expense of inputs and a means of estimating or adjusting the biological input differences between genotypes. This study assessed both cumulative and annual outputs over four years early in ewe lifetime and adjusted output relative to metabolic body weight since it was not possible to measure nutritional intake by the various genotypes under essentially year-around grazing. The cumulative production levels for both number and weight of lamb weaned per ewe entering the flock are 15 to 20% higher than reported by Hohenboken and Clarke (1981) from a study of several crossbred ewe genotypes evaluated by repeated lambings to Hampshire rams at the same location. They reported greater variation among genotypes with Finn-sired ewes being most prolific and weaning an average of 4.7 lambs per ewe over their second through fifth years. This compares to 5.2 lambs weaned for Polypay-sired ewes in this trial. It appears that much of the difference may be due to higher lamb survival in this trial as reported by Nawaz and Meyer (1991).

The influence of Polypay vs Coopworth genes on ewe performance, at least for some traits, appeared dependent upon whether they were derived from the sire or dam. As explained by Nawaz and Meyer (1991) this may be due to the upgrading background of Coopworth-type ewes serving as dams for generation of the various genotypes. The effect was particularly apparent for fleece weight where daughters of Coopworth sires produced

31% more wool than Polypay-sired ewes but daughters from dams of the two genotypes did not differ.

Among the numerous components contributing to cumulative productivity over the four years of the trial, daughters of Polypay sires consistently ranked either first or second among the three breeds while Coopworth-sired ewes were consistently second or third. Polypay-sired ewes exhibited highest survival for both ewes and lambs, possibly influenced by a favorable effect of Finn genes. The advantage of 1% in annual ewe survival is consistent with the difference reported by Ercanbrack and Knight (1985) for  $\frac{1}{4}$  Finn ewes vs non-Finn ewes during the two- through five-year-old lambing portion of their longevity trial. Hohenboken and Clarke (1981) found that under irrigated pasture grazing at our location, Finn-sired ewes survived longer than daughters from three other white-faced sire breeds; however, under continuous management on hill pastures, Finn-sired ewes exhibited lowest average longevity.

The superior survival of Polypay-derived ewes combined with the highest conception rate and near highest litter size resulted in their producing the greatest cumulative weight of lamb weaned per ewe entering the trial. Based on average weight of lamb weaned per ewe mated, Polypay-sired ewes were 11% superior to Coopworth-sired ewes. Results from the study of Ercanbrack and Knight (1985) indicate  $\frac{1}{4}$ -Finn whiteface ewes averaged 27% more weight of lamb weaned per ewe mated over their two-through five-year-old lambings when producing blackface crossbred lambs. The closest comparison in this trial is between Polypay and Coopworth ewes where the advantage of the  $\frac{1}{4}$ -Finn ewes was 22%.

Suffolk-sired ewes excelled in weaning weight of their lambs, a reflection of the breed's high growth characteristics (Dickerson et al.,



1975; Oltenacu and Boylan, 1981; Fogarty et al., 1985) and milk production (Snowder and Glimp, 1991). They also had the highest litter size, but this was partially offset by having the lowest conception rate. The net effect was that daughters of Polypay and Suffolk rams produced the same weight of lamb weaned per ewe mated; however, the poorer survival of Suffolk-sired ewes resulted in lower cumulative lamb production per ewe entering the study. Hohenboken and Clarke (1981) also reported lower survival of Suffolk-sired than whiteface crossbred ewes when managed under hill conditions although survival did not differ under irrigated pasture conditions.

Coopworth-sired ewes suffered both the lowest litter size and light lamb weaning weights, particularly for twins. As a consequence, they produced the least weight of lamb weaned, both on an annual basis per ewe mated and in total weight per ewe entering the trial. This may be related to the Romney component of the Coopworth breed. Hohenboken and Clarke (1981) found lower cumulative four-year lamb production from Romney-sired ewes than from ewes sired by rams of the Finn or Dorset breeds, both of which are components of Polypays.

Estimation of relative efficiency by dividing production per ewe mated by metabolic body size resulted in the lighter Coopworth-sired ewes surpassing the 10 kg heavier Suffolk-sired ewes. The 56 kg average weight of Coopworth-sired ewes is typical of mating weights in New Zealand where the breed was developed as a dual purpose meat/wool breed managed year round under intensive pasture grazing (Sumner and McCall, 1989). The 30% greater wool production of Coopworth-sired ewes over other genotypes accentuates the developmental emphasis placed on the breed in its native environment where wool plays a major role in determining gross income from

a ewe flock. Comparing total ewe output by use of an index combining weight of lamb weaned with three times ewe fleece weight, as done by Oltenacu and Boylan (1981) and Gallivan et al. (1987), resulted in only a 2% difference between daughters of the highest and lowest of the three sire breeds.

The importance of reproductive rate in determining weight of lamb weaned is illustrated by the 54% greater average litter weight of ewes weaning twins versus those weaning singles (Table 3.2). Black (1982) estimated a 32% superiority for weight of lamb weaned by twinning Coopworth ewes over those raising single lambs under New Zealand intensive grazing conditions. Mature ewes and those from Suffolk or Polypay sires showed the greatest proportionate weaning weight increase from rearing a second lamb, probably an indication of greater ability to respond to cumulative milk demands of twins.

The general lack of heterosis exhibited by Coopworth X Polypay reciprocal cross ewes for reproductive, maternal and survival traits is in contrast to numerous previous crossbreeding reports (e.g. Nitter, 1978; Clarke et al., 1982; Fogarty, 1984; Gallivan et al., 1987), and may be due to the high level of heterozygosity likely to be present in these two newly-developed synthetic breeds. The pattern of ewe mortality was not related to body weight, and neither appeared to be influenced by heterotic effects. Both body weight and reproductive performance were lowest in the first year of the trial, as expected for young ewes (Dickerson and Glimp, 1975). Thereafter there was little relation between body weight and other traits apart from the year with highest May fleece weights (1988) also being the year with heaviest September mating weights. The year of highest wool production also coincided with the only year in which a

decrease in wool production resulted from rearing of two vs one lamb. The average fleece weight decline of 2% due to rearing of a second lamb is considerably less than the 6% reported by Sumner and McCall (1989) and probably reflects the management policy of attempting to place twin-nursing ewes on pasture providing greater forage availability.

### **Implications**

Ranking of the three sire breeds clearly depends upon ranking criteria: Suffolk-sired ewes weaned the heaviest lambs, Polypay-sired ewes weaned the most lambs and Coopworth-sired ewes produced the most wool. Suffolk and Polypay-sired ewes exceed Coopworths in gross lamb production; however, adjusting lamb production for ewe size reveals Coopworth-sired ewes to be more efficient than the heavier Suffolk-sired ewes. Combining lamb and wool production to assess gross output results in very little performance difference among the three sire breeds. When gross output is adjusted for ewe body weight, Coopworth sires produced the most efficient daughters while Suffolks produced the least efficient. Accordingly, the choice of genotypes for a particular production system is dependent upon several input and output parameters superimposed on genetic differences.

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TABLE 3.1. NUMBER OF EWES BEGINNING TRIAL, % OF INITIAL EWES REMAINING AND % OF LAMBING EWES WEANING LAMBS BY YEAR

LAMBING EWES WEANING LAMBS BY YEAR									
		% Surviving				% Weaning lambs			
	No.	1987	1988	1989	1990	1987	1988	1989	1990
Sire breed:									
Coopworth (C)	87	100	95	89	84	86	95	93	94
Polypay (P)	93	100	96	93	88	96	98	96	94
Suffolk(S)	93	100	96	89	84	96	94	92	92
Dam breed:									
Coopworth	94	100	98	95	90	90	95	92	92
Polypay	179	100	94	88	83	94	96	95	94
Ewe genotype:									
C X C	25	100	100	92	92	84	91	91	91
P X P	58	100	95	91	86	98	98	94	94
P X C	35	100	97	94	91	91	97	100	94
C X P	62	100	94	87	81	87	96	94	96
S X C	34	100	97	97	88	94	97	84	89
S X P	59	100	95	85	81	96	92	98	94
Overall	273	100	96	91	87	92	95	94	93

TABLE 3.2. LEAST SQUARE MEANS AND STANDARD ERRORS FOR ANNUAL EWE SURVIVAL, CONCEPTION RATE, LITTER SIZE, PROPORTION OF LAMBING EWES WEANING LAMBS AND LITTER WEANING WEIGHT OF EWES WEANING LAMBS

	Survival	Conception	Litter	Ewes weaning	Weight weaned (kg)	
		rate	size	lambs	Mean	Twin/Single <sup>a</sup>
Sire breed:						
Coopworth (C)	.95	.96	1.57	.91 <sup>d</sup>	38.58 <sup>d</sup>	1.48
Polypay (P)	.96	.97	1.65	.95 <sup>b</sup>	40.54 <sup>c</sup>	1.58
Suffolk (S)	.95	.94	1.68	.93 <sup>c</sup>	43.42 <sup>b</sup>	1.56
(Avg SE)	(.02)	(.01)	(.03)	(.01)	(.65)	
Dam breed:						
Coopworth	.97	.96	1.53 <sup>c</sup>	.92	39.78 <sup>c</sup>	1.51
Polypay	.94	.96	1.73 <sup>b</sup>	.95	41.91 <sup>b</sup>	1.57
(Avg SE)	(.01)	(.01)	(.02)	(.01)	(.52)	
Ewe genotype:						
C X C	.97	.95	1.44 <sup>d</sup>	.90	37.80 <sup>d</sup>	1.44
P X P	.95	.97	1.75 <sup>b</sup>	.96	41.21 <sup>c</sup>	1.59
P X C	.97	.98	1.54 <sup>cd</sup>	.95	39.87 <sup>cd</sup>	1.58
C X P	.93	.97	1.69 <sup>bc</sup>	.92	39.35 <sup>cd</sup>	1.52
S X C	.96	.94	1.61 <sup>bc</sup>	.91	41.66 <sup>c</sup>	1.51
S X P	.93	.95	1.75 <sup>b</sup>	.96	45.17 <sup>b</sup>	1.61
(Avg SE)	(.02)	(.01)	(.04)	(.02)	(1.13)	
Year:						
1987	1.00	.96	1.52 <sup>c</sup>	.92	34.30 <sup>d</sup>	1.35
1988	.96	.94	1.63 <sup>b</sup>	.95	42.90 <sup>c</sup>	1.57
1989	.94	.97	1.72 <sup>b</sup>	.93	45.39 <sup>b</sup>	1.64
1990	.95	.97	1.66 <sup>b</sup>	.93	43.17 <sup>c</sup>	1.61
(Avg SE)	(.01)	(.01)	(.03)	(.02)	(.75)	
Overall	.95	.96	1.63	.94	40.85	1.54

<sup>a</sup>Ratios of litter weaning weight of ewes weaning two vs one lamb.

<sup>b,c,d</sup>Means within a group that do not have a common superscript differ (P<.05).



TABLE 3.3. LEAST SQUARE MEANS AND STANDARD ERRORS FOR NUMBER OF PRODUCTIVE YEARS, CUMULATIVE NUMBER AND WEIGHT OF LAMBS WEANED, EWE MATING WEIGHTS, ANNUAL WEIGHT OF LAMB WEANED PER EWE MATED AND RELATIVE EFFICIENCY FOR LAMB PRODUCTION

	No. years	No. lambs	Lamb wt (kg)	Ewe wt (kg)	Annual lamb wt (kg)	Relative efficiency <sup>a</sup>
Sire breed:						
Coopworth (C)	3.27 <sup>c</sup>	4.65 <sup>c</sup>	128.1 <sup>c</sup>	56.1 <sup>d</sup>	34.7 <sup>c</sup>	91
Polypay (P)	3.53 <sup>b</sup>	5.15 <sup>b</sup>	144.5 <sup>b</sup>	59.2 <sup>c</sup>	38.4 <sup>b</sup>	97
Suffolk (S)	3.25 <sup>c</sup>	4.87 <sup>c</sup>	141.4 <sup>b</sup>	66.7 <sup>b</sup>	38.3 <sup>b</sup>	88
(Avg group SE)	(.11)	(.22)	(5.4)	(.4)	(.9)	
Dam breed:						
Coopworth	3.37	4.65 <sup>c</sup>	134.7	61.8 <sup>b</sup>	35.3 <sup>c</sup>	86
Polypay	3.32	5.12 <sup>b</sup>	141.4	59.4 <sup>c</sup>	39.0 <sup>b</sup>	98
(Avg group SE)	(.08)	(.17)	(4.8)	(.4)	(.7)	
Ewe genotype:						
C X C	3.24 <sup>c</sup>	4.40 <sup>c</sup>	123.5 <sup>c</sup>	57.3 <sup>e</sup>	32.3 <sup>b</sup>	83
P X P	3.48 <sup>bc</sup>	5.38 <sup>b</sup>	145.9 <sup>b</sup>	58.3 <sup>e</sup>	39.4 <sup>c</sup>	100
P X C	3.57 <sup>b</sup>	4.91 <sup>bc</sup>	143.2 <sup>bc</sup>	60.1 <sup>d</sup>	37.5 <sup>c</sup>	93
C X P	3.29 <sup>c</sup>	4.89 <sup>bc</sup>	132.8 <sup>bc</sup>	54.8 <sup>f</sup>	37.0 <sup>c</sup>	98
S X C	3.29 <sup>c</sup>	4.64 <sup>c</sup>	137.4 <sup>bc</sup>	68.1 <sup>b</sup>	36.0 <sup>c</sup>	81
S X P	3.20 <sup>c</sup>	5.10 <sup>b</sup>	145.5 <sup>b</sup>	65.2 <sup>c</sup>	40.6 <sup>c</sup>	95
(Avg group SE)	(.16)	(.29)	(7.9)	(.6)	(1.3)	
Overall	3.35	4.89	138.0	60.6	37.2	

<sup>a</sup>Annual weight of lamb weaned per ewe mated + (mean ewe weight)<sup>0.75</sup>; values relative to most efficient genotype.

<sup>b,c,d,e,f</sup>Means within a group that do not have a common superscript differ (P<.05)

TABLE 3.4. LEAST SQUARE MEANS AND STANDARD ERRORS FOR YEARLY WOOL PRODUCTION (kg)  
OF EWES REARING LAMBS

	1988		1989		1990		Overall	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean
Sire breed:								
Coopworth (C)	70	3.95 <sup>a</sup>	73	3.66 <sup>a</sup>	59	3.81 <sup>a</sup>	202	3.80 <sup>a</sup>
Polypay (P)	81	3.06 <sup>b</sup>	81	2.82 <sup>b</sup>	70	2.81 <sup>b</sup>	232	2.89 <sup>b</sup>
Suffolk (S)	75	3.07 <sup>b</sup>	77	2.80 <sup>b</sup>	65	2.75 <sup>b</sup>	217	2.87 <sup>b</sup>
(Avg group SE)		(.07)		(.07)		(.08)		(.04)
Dam breed:								
Coopworth	78	3.41	81	3.10	73	3.08	232	3.20
Polypay	148	3.30	150	3.08	121	3.17	419	3.18
(Avg group SE)		(.06)		(.06)		(.06)		(.03)
Ewe genotype:								
C X C	19	4.00 <sup>a</sup>	21	3.68 <sup>a</sup>	18	3.85 <sup>a</sup>	58	3.84 <sup>a</sup>
P X P	50	2.92 <sup>b</sup>	50	2.75 <sup>b</sup>	40	2.87 <sup>b</sup>	140	2.84 <sup>b</sup>
P X C	31	3.18 <sup>b</sup>	31	2.89 <sup>b</sup>	30	2.74 <sup>b</sup>	92	2.94 <sup>b</sup>
C X P	51	3.89 <sup>a</sup>	52	3.65 <sup>a</sup>	41	3.78 <sup>a</sup>	144	3.77 <sup>a</sup>
S X C	28	3.03 <sup>b</sup>	29	2.74 <sup>b</sup>	25	2.65 <sup>b</sup>	82	2.81 <sup>b</sup>
S X P	47	3.10 <sup>b</sup>	48	2.86 <sup>b</sup>	40	2.85 <sup>b</sup>	135	2.94 <sup>b</sup>
(Avg group SE)		(.10)		(.10)		(.10)		(.06)
Rearing rank:								
Single	90	3.34	68	3.11	86	3.13	244	3.21
Twin	136	3.20	163	3.08	108	3.12	407	3.17
(Avg group SE)		(.06)		(.06)		(.06)		(.03)
Overall	226	3.36	231	3.09	194	3.12	651	3.19

<sup>a,b</sup>Means within a group that do not have a common superscript differ ( $P < .01$ ).

**GENOTYPE AND MATING WEIGHT EFFECTS ON OVULATION RATE, LITTER SIZE  
AND UTERINE EFFICIENCY OF COOPWORTH, POLYPAY AND CROSSBRED EWES**

**CHAPTER 4**

**Abstract**

Six genotypes were produced by mating Coopworth (C), Polypay (P) and Suffolk (S) rams to Coopworth-type and Polypay ewes. In 1989, body weight and ovulation rate (OR) were recorded for 188 naturally ovulating five- and six-year old ewes representing all six genotypes, and litter size (LS) was recorded for the 174 (93%) which lambled to the observed ovulation. Overall OR and LS averaged 1.85 and 1.71, respectively. Mean OR and LS did not differ among daughters of the various sire breeds; however, daughters of Polypay dams exhibited both higher OR and LS than daughters of Coopworth-type ewes. Heterosis estimates for OR and LS were 6% and 7%, respectively. Overall uterine efficiency (UE) of ewes conceiving to twin ovulations was .83. Polypay-derived ewes exhibited higher UE than other genotypes. Pre-mating body weight (BW) had statistically significant but small effects on both OR and LS. Overall estimates of OR and LS response to a 10% increase in BW were 5% and 3%, respectively. Only Polypay-sired ewes showed a significant relationship between BW and reproductive performance, the estimated responses to a 10% BW increase being 9% for OR and 6% for LS. BW variation had no effect on UE of ewes conceiving to twin ovulations.

## Introduction

Reproductive rate is a major factor affecting returns from sheep production, particularly if the proportion of income from lamb is high relative to wool. In the 1970's the Polypay breed was developed in the US as a highly prolific dual purpose breed that incorporated Finn genes (Hulet et al., 1984). At the same time the dual purpose Coopworth breed was evolving in New Zealand with prolificacy being one of its selection criteria.

While genetic variation is important in determining a flock's prolificacy, ewe nutritional management also has an important role. Ewe physiological status at mating has long been known to affect reproductive performance and is the basis for the common pre-mating nutritional practice of flushing (Rattray et al., 1981). Coop (1966) postulated that a portion of pre-mating nutrition effects on reproduction were a consequence of changes in body condition. New Zealand sheep producers are commonly advised to insure adequate body condition by achieving target ewe mating weights. Studies such as that of West et al. (1991) have demonstrated that poor body condition ewes achieve lower embryo success, resulting in only a portion of ovulation increases from flushing being realized as lambs born.

This trial studied both genetic and body weight effects on reproductive performance by using ewes derived from Polypay and/or Coopworth origin to examine the effect of naturally occurring body weight variation on ovulation rate and litter size.

### Materials and Methods

**Animals.** Six genotypes were produced by mating Polypay and Coopworth-type ewes to purebred Polypay, Suffolk and imported Coopworth rams. The Coopworth-type ewes had been produced by two to three generations of backcrossing commercial medium wool white face ewes to Coopworth rams. Ewes were generated in 1984 and 1985, using the same rams from each sire breed in both years. Prior to this study no culling on performance had been practiced at any stage. In 1989, the 5- and 6-year-old ewes were rotationally grazed as a single flock on dry pasture from lamb weaning in May through mating. Ewes were exposed to teaser rams for 3 wk before being group mated to harnessed Hampshire rams beginning August 25. All ewes were weighed before ram introduction. Ewes marked by rams during each of the first 3 wk of mating were examined by laparoscopy to measure ovulation rate. A total of 188 ewes were examined.

Following mating, ewes were grazed on ryegrass/white clover pasture supplemented only with conserved pasture silage until late gestation when they were moved indoor for lambing and received hay and concentrate supplementation. Ewes lambd under close supervision, and lambing performance was recorded for each ewe.

**Data handling and analyses.** The lambing record for each ewe was checked against mating and laparoscopy records to delete from the analysis any animals conceiving to a subsequent estrus. The ovulation records of several ewes with observed litter size greater than recorded ovulation rate were adjusted upward to equal litter size. This was done in light of the close surveillance of ewes at lambing and the recognized difficulty of comprehensive laproscopic observation of ovaries in ewes having

experienced multiple previous pregnancies. Adjusted records appeared to be randomly distributed across genotypes.

The effect of body weight on reproductive traits was assessed within genetic groups by inclusion of body weight as a covariate in separate analyses for each group. Resulting sums of squares and cross products were pooled over the six genotypes to derive a pooled regression coefficient. It was considered inappropriate to include mating weight as a covariate in the overall model for analyzing reproductive traits since breeds differed in mean mating weight. Adjusted ovulation rate and litter size were analyzed using two approaches - logistic regression assuming multinomial distribution and by general linear model procedures (GLM, SAS, 1986) assuming underlying normal distribution (Turner and Young, 1969). The two methods generated similar results and SAS GLM results are presented in this paper. Mating weights were also analyzed by SAS GLM. The statistical model used to analyze all traits contained sire and dam breeds and their interaction, all regarded as fixed effects. Ewe age class and its interactions with other main effects were tested and dropped from the model after being found non significant at  $P > .50$ . Multiple comparisons were made among sire breed and genotype means using the Student-Newman-Kuels procedure (Sokal and Rohlf, 1969)

## Results

Analysis of variance results for mating weight and reproductive traits are presented in Table 4.1 and least square means are presented in Table 4.2. Overall mean body weight was 64 kg with the two groups of Suffolk-sired ewes averaging 9 kg heavier than other genotypes ( $P<.01$ ). Daughters of the two dam breeds did not differ in average mating weights and there was no evidence of interaction between sire and dam breeds. The heterosis estimate for body weight in Coopworth X Polypay reciprocal crosses was -3%.

The overall mean ovulation rate was 1.85 with 75% of ewes being twin ovulators. Genotype ovulation rate means ranged from 1.68 for Coopworth to 1.98 for C X P ewes. Daughters of Polypay dams averaged .17 higher ovulation rate than daughters of Coopworth-type dams ( $P<.05$ ). Sire breeds did not differ in ovulation rate. The heterosis estimate for ovulation rate in Coopworth X Polypay reciprocal crosses was 6% but there was no indication of sire by dam breed interaction.

The pooled regression coefficient of ovulation rate on mating weight (.013) was small but significant ( $P<.01$ ; Table 4.3). Mating weight and ovulation rate were positively related in all six genotypes; however, only in straightbred Polypays was the regression coefficient significant (.024;  $P<.01$ ). Coopworth and the Coopworth X Polypay reciprocal crosses showed the least effect of body weight variation on ovulation rate. Daughters of both Polypay sires and Polypay dams showed an effect of mating weight on ovulation rate ( $P<.01$ ) but the effect was not significantly different from zero for any of the other sire or dam breeds. Conception rate was high with 93% of marked ewes lambing to the first estrus following ram

introduction. Apart from S X P ewes with an 86% conception rate, all genotype exhibited 92% or higher conception to first marking.

Mean litter size followed the same pattern as ovulation rate with the six genotypes ranking in the same order for the two traits. Overall litter size averaged 1.71 with 64% of lambing ewes producing twins. Sire breeds did not differ in mean litter size of their daughters although Polypay sires produced the most prolific offspring. Daughters of Polypay dams produced .28 more lambs/ewe than daughters of Coopworth-type dams ( $P < .05$ ), an 18% superiority in litter size compared to a 10% superiority in ovulation rate. The heterosis estimate for litter size in Coopworth X Polypay crosses was 7%.

The linear effect of mating weight on litter size was less than its effect on ovulation rate (pooled regression coefficient = .009,  $P = .07$ ), but the effect remained positive in five of the six genotypes (Table 4.3). Body weight effect on reproduction remained largest for the straightbred Polypay ewes ( $P < .05$ ) where a 10% increase in body weight would be expected to produce a 6% increase in litter size. Among parental breeds, only daughters of Polypay sires showed a significant effect between mating weight and litter size. The mean expected within-genotype effect of a 10% mating weight increase was less than a 5% increase in ovulation rate and a 3% increase in litter size.

Uterine efficiency, defined as the marginal litter size increase due to a unit increase in ovulation rate (Meyer, 1985), can be calculated for ewes lambing to twin ovulations as either proportion producing twins or mean litter size minus 1, and is shown in Table 4.2. Overall mean uterine efficiency for twin ovulators was .83 with little variation among sire



breeds although Polypays were highest at .88. Daughters of Polypay ewes had a mean uterine efficiency of .90 compared to .76 for daughters of Coopworth-type ewes ( $P < .05$ ). All three genotypes from Polypay dams were well above the three genotypes from Coopworth-type dams. No heterosis was observed for uterine efficiency among Coopworth X Polypay crosses. Examination of ovulation pattern effects on uterine efficiency revealed little difference between unilateral and bilateral twin ovulators. Triplet ovulators exhibited very high embryo success with 11 ewes producing 31 lambs.

### Discussion

The breakdown of litter size into its components indicates that the high prolificacy of Polypays is due to superiority in both ovulation rate and uterine efficiency. The overall uterine efficiency of .83 observed in the trial for ewes conceiving to twin ovulation is higher than for any of six New Zealand trials (range of .59 to .77 with at least 100 twin ovulators per trial) reported by Meyer (1985) and higher than the values of .70 and .66 reported for twin ovulators by West et al. (1991) from two trials conducted at the same location as the present trial. It is also greater than the expected value of .70 derived by Hanrahan (1982) or the value of .72 which can be derived from embryo survival data reported by Bradford et al. (1986a). One possible explanation for the high UE rate observed in this trial may be the greater maturity of ewes since they were older than all but a small proportion of ewes in any of the other trials. Little is known regarding age effects on uterine efficiency, although Meyer and Clarke (1982) found no age differences among ewes ranging from two through five years old.

Although the Polypay breed was originally composed of only 25% Finn genes (Hulet et al., 1984), the Finn contribution appears to have given the Polypay superiority in both ovulation rate and uterine efficiency. The net result was a proportionally greater Polypay superiority in litter size than in ovulation rate. The Finn effect on litter size of crossbreds is well documented from studies at numerous locations (Hanrahan, 1974; Meyer et al., 1977; Dickerson, 1977; Thomas and Whiteman, 1979; Oltenacu and Boylan, 1981). Fewer studies have examined Finn effects on either ovulation rate or uterine efficiency effects. Meyer and Bradford (1973)

reported an ovulation rate increase of about .6 ova (2.6 vs. 2.0) for Finn X Targhee vs Targhee ewes. Uterine efficiency was also superior for the Finn crosses, being .82 vs .56 for twin ovulators and .55 vs .27 for triple ovulators. Among nine crossbred genotypes examined in New Zealand, Meyer (1979) reported the highest ovulation rate for Finn halfbreds followed by Finn quarterbreds. Uterine efficiency among twin ovulators was likewise highest for halfbreds (.92) followed by quarterbreds (.88) at values very similar to those observed for Polypay-derived ewes in this trial. Ricordeau et al. (1982) and Bradford et al. (1986b) have reported similar high embryo survival for the prolific Romanov and Javanese breeds, respectively.

The reproductive superiority of Polypays vs Coopworths was greater when they were compared as dam breeds than when compared as sire breeds. As explained by Nawaz and Meyer (1991) this is probably due to the difference in genetic background of the Coopworth sires and the Coopworth-type dams. The rams were from an imported group selected on the basis of superior expected genetic merit, much as was done for Polypay sires. The Coopworth-type dams on the other hand, were the result of two to three generations of upgrading a commercial medium wool white-face flock with Coopworth rams from an earlier importation. The difference between daughters of Coopworth sires and Coopworth-type dams also extended to lamb growth (Nawaz and Meyer, 1991) and ewe wool production (Nawaz et al., 1991).

The small average effect of ewe body weight variation on reproductive performance suggests that either body weight was not a good indicator of body condition or that body condition levels were above some

critical level such that variation did not influence reproductive performance. The mean body weight of 64 kg suggests the latter may have been the case. Our estimate of .013 ova/kg is considerably lower than the average estimate of .048 ova/kg reported by Bradford and Quirke (1986) for Targhee, Barbados and crossbred ewes. The difference may be due to either the younger age (mostly three-year- old or younger) or poorer body condition of their ewes (Targhees averaged 55 kg) as commented on by the authors. The very high single estrus conception rate of 93% observed in this trial also suggests that the ewes were not reproductively disadvantaged by their body condition.

The positive relationship between body weight and reproduction in Polypay-derived ewes suggests their ability to respond to increasing body condition may extend to a higher body condition threshold. Meyer and Bradford (1973) found ovulation rate of Finn halfbreds to be more responsive than observed for straightbred Targhees when both were placed on improved nutrition.

The relative lack of heterosis for reproductive traits found in Coopworth X Polypay crosses is atypical of previous reports (eg. Nitter, 1978; Fogarty et al., 1984) and may reflect the high level of heterozygosity already expected to be present in each of these two recently formed breeds.

### Implications

Polypay breeding had a marked positive effect on ewe reproduction. This was the result of both higher ovulation rate and higher embryo success among ewes conceiving to twin ovulations. The low pooled within-genotype regression coefficient between body weight and reproduction indicates little advantage for the heavier ewes. This suggests that increasing body conditions of ewes already averaging 64 kg at mating may not result in improved reproductive performance. Polypay-sired ewes appear to be an exception and may continue to respond until reaching some higher mean body weight.

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TABLE 4.1. SUMMARY OF F STATISTICS FROM ANALYSIS OF VARIANCE FOR EWE MATING  
WEIGHT (kg) AND REPRODUCTIVE TRAITS

Source	df	Mating weight	Ovulation rate	Litter size	Uterine efficiency <sup>a</sup>
Sire breed (SB)	2	20.48**	0.30	0.94	0.71
Dam breed (DB)	1	0.86	5.35*	10.95**	4.51*
SB X DB	2	0.62	0.77	0.68	0.03
Residual m.s.		71.12	0.23	0.28	0.12
(Residual df)		(182)	(182)	(168)	(124)

<sup>a</sup>Ewes conceiving to twin ovulations only.

\*\*P<.01; \*P<.05.

TABLE 4.2. LEAST SQUARE MEANS AND STANDARD ERRORS FOR EWE MATING WEIGHT (kg),  
OVULATION RATE, LITTER SIZE AND UTERINE EFFICIENCY

	No.	Mating weight	Ovulation rate	<u>Litter size</u>		<u>Uterine efficiency</u>	
				No.	Mean	No.	Mean <sup>a</sup>
Sire breed:							
Coopworth (C)	68	60.1 <sup>c</sup>	1.83	64	1.68	49	.79
Polypay (P)	61	62.5 <sup>c</sup>	1.89	57	1.79	41	.88
Suffolk (S)	59	69.8 <sup>b</sup>	1.84	53	1.66	40	.83
(Avg group SE)		(1.1)	(.06)		(.07)		
Dam breed:							
Coopworth	70	64.7	1.77 <sup>c</sup>	66	1.57 <sup>c</sup>	42	.76 <sup>c</sup>
Polypay	118	63.6	1.94 <sup>b</sup>	108	1.85 <sup>b</sup>	88	.90 <sup>b</sup>
(Avg group SE)		(0.9)	(.05)		(.05)		
Ewe genotype:							
C X C	22	61.3 <sup>c</sup>	1.68	21	1.48 <sup>c</sup>	14	.71
P X P	36	62.9 <sup>c</sup>	1.94	34	1.88 <sup>b</sup>	26	.96
P X C	25	62.1 <sup>c</sup>	1.84	23	1.70 <sup>b</sup>	15	.80
C X P	46	58.9 <sup>c</sup>	1.98	43	1.88 <sup>b</sup>	35	.86
S X C	23	70.8 <sup>b</sup>	1.78	22	1.55 <sup>c</sup>	13	.77
S X P	36	68.8 <sup>b</sup>	1.89	31	1.77 <sup>b</sup>	27	.89
(Avg group SE)		(1.6)	(.08)		(.09)		
Overall	188	64.1	1.85	174	1.71	130	.83

<sup>a</sup>Ewes conceiving to twin ovulations only.

<sup>b,c</sup>Means in the same column within categories without common letters in their superscript differ (P<.05)

TABLE 4.3. REGRESSION OF OVULATION RATE (OR) AND LITTER SIZE (LS) ON EWE MATING WEIGHT (WT) AND % CHANGE EXPECTED FROM 10 % INCREASE IN MATING WEIGHT

	Coefficients		% change	
	$b_{OR/WT}$	$b_{LS/WT}$	OR	LS
Sire breed:				
Coopworth (C)	.005	.001	1.6	.4
Polypay (P)	.026**	.018*	8.6	6.3
Suffolk (S)	.009	.010	3.4	4.2
Dam breed:				
Coopworth	.010	.008	3.7	3.3
Polypay	.015**	.009	4.9	3.1
Ewe genotype:				
C X C	.004	.003	1.5	1.2
P X P	.024**	.019*	7.8	6.4
P X C	.007	.011	2.4	4.0
C X P	.006	-.001	1.8	-0.3
S X C	.030 <sup>+</sup>	.016	11.9	7.3
S X P	.012	.007	4.4	2.7
Pooled <sup>a</sup>	.013**	.009 <sup>+</sup>	4.5	3.2

<sup>a</sup>Pooled estimate from within genotypes.

\*\*P<.01; \*P<.05; <sup>+</sup>P<.10.

**WOOL PRODUCTION AND LAMB WEANING WEIGHT OF RAMBOUILLET, KAGHANI  
AND CROSSBRED EWES**

**CHAPTER 5**

**Abstract**

In order to upgrade native sheep, Rambouillet (R) rams were mated to Kaghani (K) ewes to generate F1 (R X K) crossbred ewes. Crossbred ewes were backcrossed to Rambouillet rams to produce B1(R X F1), B2(R X B1) and B3(R X B2) genotypes. Weaning weight of 2605 lambs and wool weight of 2378 mature ewe records, representing R, K, F1, B1, B2 and B3 genotypes, were analyzed to compare genetic variation among genotypes produced during upgrading process and identify genotypes of the highest performance. Performance of Rambouillets was also evaluated under semi-temperate climate. Data were adjusted for yearly variation considering Rambouillet as a control. Genotypes influenced in lamb weaning weight ( $P<.01$ ). B1 lambs were heaviest (18.4 kg) followed in order by B2, F1, B3, R and K lambs (18.3, 17.9, 16.9, 16.8 and 13.2 kg, respectively). The highest wool production was 2.5 kg from R ewes followed by B2(2.3), B3(2.3), F1(2.0) and K(1.2) ewes ( $P<.01$ ). Reproduction, growth and wool production of Rambouillets deteriorated significantly after the first decade of their importation. Compared with the first phase (1959-1971), litter size, birth weight, lamb weaning weight and wool production declined by 20, 23, 32 and 36%, respectively, in the second phase (1972-1988).

### Introduction

Pakistan has over 20 million sheep. Slow growth and low reproduction rates are major concerns of the sheep industry in Pakistan. Meat is the major product of sheep production and it accounts for 20% of the total meat production in the country. Pakistan requires fine wool for apparel purposes but lacks fine wool sheep breeds. Increases in meat and wool production in the last decade are probably attributable to increases in sheep numbers without improvements in animal performance. High prices of wool and meat in the country suggest scarcity of both; however, due to limited land resources, increases in numbers of animals cannot be continued indefinitely. Adequate feeding of small numbers of highly productive animals is more economical than inadequate feeding of large numbers of lowly productive animals. Therefore, emphasis should be on increasing meat and wool production by improving genetic merits of animals. Improvement in productive traits could be made genetically through either selection or crossbreeding.

In Pakistan 61 percent of the sheep population are in flocks of 1 to 50 animals; only 7% of sheep are managed in flocks of 200 or more head. The large flocks are of migratory nature, managed mostly by illiterate people unfamiliar with scientific selection principles. There are no record keeping practices for evaluation of any flock in the private sector. All these factors suggest that the opportunity for genetic improvement of sheep in Pakistan through selection is probably limited. Therefore improvement efforts have concentrated on upgrading local sheep through crossbreeding, including use of Rambouillet sheep for grading up local Kaghani sheep. The present study was designed to compare weaning

weights and wool production of various genotypes generated during the upgrading process. Assessment is also made of the performance of Rambouillets over time in Pakistan.

## Materials and Methods

***Animals and Management.*** A Rambouillet breeding flock of 80 ewes and 5 rams was imported into Pakistan from the USA in 1957. The flock was kept at the Jaba Livestock Experiment Station, District Mansehra, where the climate conditions are relatively conducive for rearing such animals.

The farm originally comprised 517 hilly acres, six percent of which has been under cultivation for maize/oats to be made into silage for winter feeding. Recently an additional 60 acres of tillable land has been added to the farm to augment silage production. Most of the farm area is pasture land, covered predominantly with needle grass (*Heteropogon*) used for grazing. The average annual rain fall is 120 cm, most of which is received between July and September. Following the rainy season surplus grass is available for harvesting and conserving as hay for winter feeding. The yearly temperature varies from -3 to 38 C.

The feeding and managerial practices from 1957 through 1988 remained more or less the same depending on weather conditions and availability of feed. Feeding depended mostly on grazing during summer months, while hay and silage were fed during winter with daily supplementation of 200 to 400 grams of concentrates per head. Flushing was practiced prior to autumn breeding of ewes for spring lambing.

Since their importation, Rambouillets have been maintained as purebreds from 1957 to 1971 (phase 1) then used for crossbreeding with Kaghani sheep from 1972 to 1988 (phase 2). From 1972 to 1977 F1 ewes were generated by mating Rambouillet rams to a flock of Kaghani ewes purchased from local farmers. Ewes from the F1 crop were mated to Rambouillet rams to produce the first backcross (B1), with repeated backcrossing to produce

B2 and B3 genotypes. A total of 1183 Rambouillet (R), 58 Kaghani (K), 207 F1, 380 B1, 541 B2 and 236 B3 lambs were produced between 1972 and 1988 and their weaning weights were used for the comparison of genetic groups. Ewes were shorn annually in the month of april; and individual fleece weights were recorded between 1976 and 1987.

**Statistical Procedure.** Data were analyzed for lamb weaning weight and wool production from breeding ewes. Large year-to-year variation was observed, eg. average weaning weight of Rambouillet lambs was 100% higher in the year of highest performance than in the year of lowest performance, and difference in wool production between extreme years was 36%. Since the various genotypes were generated in different years (Figure I) weaning weight and wool data were adjusted for year effects based on the yearly variation observed in Rambouillets.

Adjusted individual records were calculated as:

$$X_{ijk} = X_{ijk} + (X_{r..} - X_{rj.})$$

where  $X_{r..}$  is the overall Rambouillet mean,

$X_{rj.}$  is the Rambouillet mean for jth year,

$X_{ijk}$  is the observation of kth individual of the ith breed group born in the jth year.

Adjusted weaning and wool weights were analyzed by general linear model procedures (SAS, 1986). Breed group and sex were used as fixed effects in the model for weaning weight analysis, whereas breed group and year were included as fixed effect in the model used for wool weight analysis. Multiple comparisons among genotype means were made using Student-Newman-Keul procedures (Sokal and Rohlf, 1969).

Wool production data from 110 Rambouillet ewes each with five



shearings were used to calculate repeatability estimates. Repeatability was calculated from variance component estimates as  $t = \sigma^2G/(\sigma^2G + \sigma^2E)$  where the between ewe variance component ( $\sigma^2G$ ) was estimated by equating the between ewe mean square to its expectation,  $\sigma^2E + K \sigma^2G$  (Becker, 1985).

## Results

Means and standard errors for lamb weaning weight and ewe wool production are shown in Table 5.1. The overall mean weaning weight was 18 kg and ranged from 13 kg for straightbred Kaghani to 18 kg for B1 (R X F1) backcross. F1 lambs were 29% heavier at weaning ( $P < .01$ ) compared with their parental means. B1 and B2 lambs were 9% heavier at weaning than that of B3 and pure Rambouillets and 39% heavier than pure Kaghani lambs.

Overall mean for wool production was 2.1 kg and ranged from 1.2 kg for Kaghani to 2.5 kg for Rambouillet ewes. Wool production from F1 ewes averaged 2.0 kg. F1 ewes showed 8% heterosis in wool production. Wool production was similar for B1, B2 and B3 ewes being 2.2, 2.3 and 2.3 kg, respectively, and 15% higher than F1 ewes ( $P < .01$ ).

Rambouillets weaning weights showed yearly variation without evidence of significant decline during the first 12 years (Phase 1) following importation. In the last years of phase 1 and early years of Phase 2, i.e. from 1970 to 1977 lamb weaning weight declined consistently and then leveled off showing yearly variation until the last part of Phase 2. The same trend was true for birth weight and litter size declined in a similar fashion. Wool production declined somewhat in the starting years of phase 1 then leveled off until the last part of phase I. A further major drop in wool production was noticed during 1970 to 1975 and then production leveled off until the last year of phase 2.

Significant differences were observed between phase 1 and phase 2 for reproduction, growth and wool production of straightbred Rambouillets. Phase 1 means for litter size, birth weight, weaning weight and wool production of Rambouillet were 1.3 lambs, 4.3, 24.8 and 3.9 kg,

respectively, (Table 5.2). The phase 2 declines were 20, 23, 32, 36% for litter size, birth and weaning weights of single lambs, and wool production, respectively. Wool production of 110 R ewes, each with five shearings, had a repeatability estimate of .50.

### Discussion

In an effort to upgrade local Kaghani Sheep by crossbreeding with Rambouillets, various genotypes ranging from 1/2 R:1/2 K to 15/16 R:1/16 K were generated. Genotypes were produced over a long period, during which administrative management changes probably affected animal performance. Even though adjustments have been made for yearly variation, one should be careful in generalizing the results of this study due to unavailability of all genotypes across all years. The results are important because they provide approximate comparisons of genotypes and suggest the need for well designed experiments in the future.

The superior performance of B1 and B2 lambs suggests that 3/4 to 7/8 Rambouillet inheritance is a desirable level for lamb production in the study environment. The superiority of B1 and B2 genotypes could be due to the advantage of a maternal heterosis effect which is not available to the F1s.

The light weaning weights of pure Kaghani lambs is indicative of the breed's low mature body weight. Weaning weights of purebred Rambouillets were lower than for crossbreds. This is typical when performance of improved breeds from temperate climates is measured under semi-temperate or tropical conditions (Alderson et al., 1982; Mohan and Acharya, 1982). Similarity in performance of B3 and Rambouillet ewes is probably due to their genetic similarity since B3 genotypes have 92% Rambouillet genes.

Rambouillets is a fine wool breed which produces good amounts of wool. The Rambouillet genes in the crossbred ewes had probably increased their wool production. The pattern of wool production indicated superiority of B1, B2 and B3 ewes over F1 ewes suggesting as Rambouillet

genes increase in the genotype the wool production increases. Repeatability of wool production was close to the findings of Cochran et al. (1984) who reported a repeatability value of .60.

As seen in Figures 1 and 2 crossbred lambs were generally heavier at weaning than straightbred Rambouillet lambs, whereas wool production was higher for Rambouillet ewes than for crossbred ewes. This anomaly suggests that the optimal level of Rambouillet breeding depends on the production objective. Numerous factors could be responsible for the significant decline in the performance of Rambouillets in the second phase. The most important could be inbreeding effects as Khan (1986) estimated mean inbreeding of 9% for this flock. Moreover, the policy of increasing the flock size of the farm without increasing land area for grazing or supplying other feed and management resources might also have affected animal performance. Consequently, relatively sub-optimal feeding and management conditions could have exaggerated inbreeding effects.

### **Implications**

Crossbreeding Rambouillet with local Kaghani breed produced improvement in both in growth and ewe wool production of crossbred animals compared with Kaghani sheep. Compared with pure Rambouillets, differential response of crossbred animals for weaning weight and wool production suggests that the optimal level of Rambouillet breeding depends on the production objective. Significant decline in all production traits during 1970 to 1977 seems to be due to both inbreeding effects and suboptimal management. Introduction of new Rambouillet genes from outside and improved feeding should improve the productivity of the flock.

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TABLE 5.1. LEAST SQUARE MEANS AND STANDARD ERRORS (kg) FOR EWE WOOL PRODUCTION AND LAMB WEANING WEIGHTS OF VARIOUS GENOTYPES

Genotype	Weaning weight			Wool production		
	No.	Mean	SE	No.	Mean	SE
Rambouillet (R)	1183	16.8 <sup>c</sup>	.11	1119	2.5 <sup>a</sup>	.01
Kaghani(K)	58	13.2 <sup>d</sup>	.39	22	1.2 <sup>d</sup>	.11
F1=(R X K)	207	17.9 <sup>b</sup>	.28	398	2.0 <sup>c</sup>	.03
B1=(R X F1)	380	18.4 <sup>a</sup>	.19	496	2.2 <sup>b</sup>	.02
B2=(R X B1)	541	18.3 <sup>a</sup>	.17	301	2.3 <sup>b</sup>	.03
B3=(R X B2)	236	16.9 <sup>c</sup>	.26	42	2.3 <sup>b</sup>	.08
Overall	2605	17.5	.23	2378	2.1	.05

<sup>a,b,c,d</sup> Means in the same column without common letters in their superscript differ (P<.05)

TABLE 5.2. REPRODUCTIVE, GROWTH AND WOOL PRODUCTION OF RAMBOUILLET PUREBREDS DURING PHASE 1 (1959-1971) AND PHASE 2 (1972- 1988)

Trait	Phase 1	Phase 2	% Change
Litter size	1.27	1.02	-20
Birth weight (kg) <sup>a</sup>	4.30	3.31	-23
Weaning weight (kg) <sup>a</sup>	24.76	16.78	-32
Wool production (kg)	3.94	2.51	-36

<sup>a</sup> Single born lambs



# LAMB WEANING WEIGHTS OF VARIOUS GENOTYPES

Figure 1

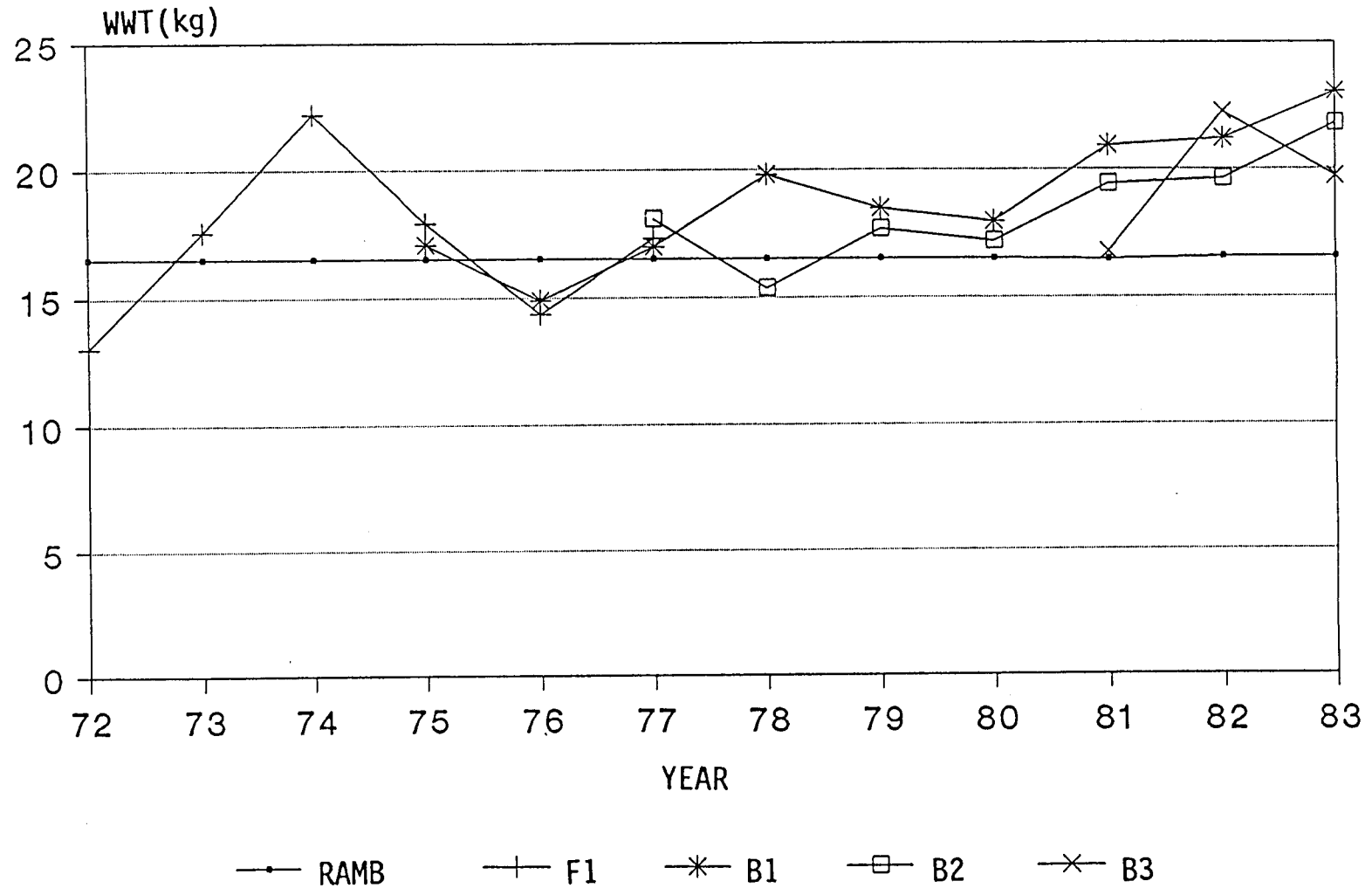
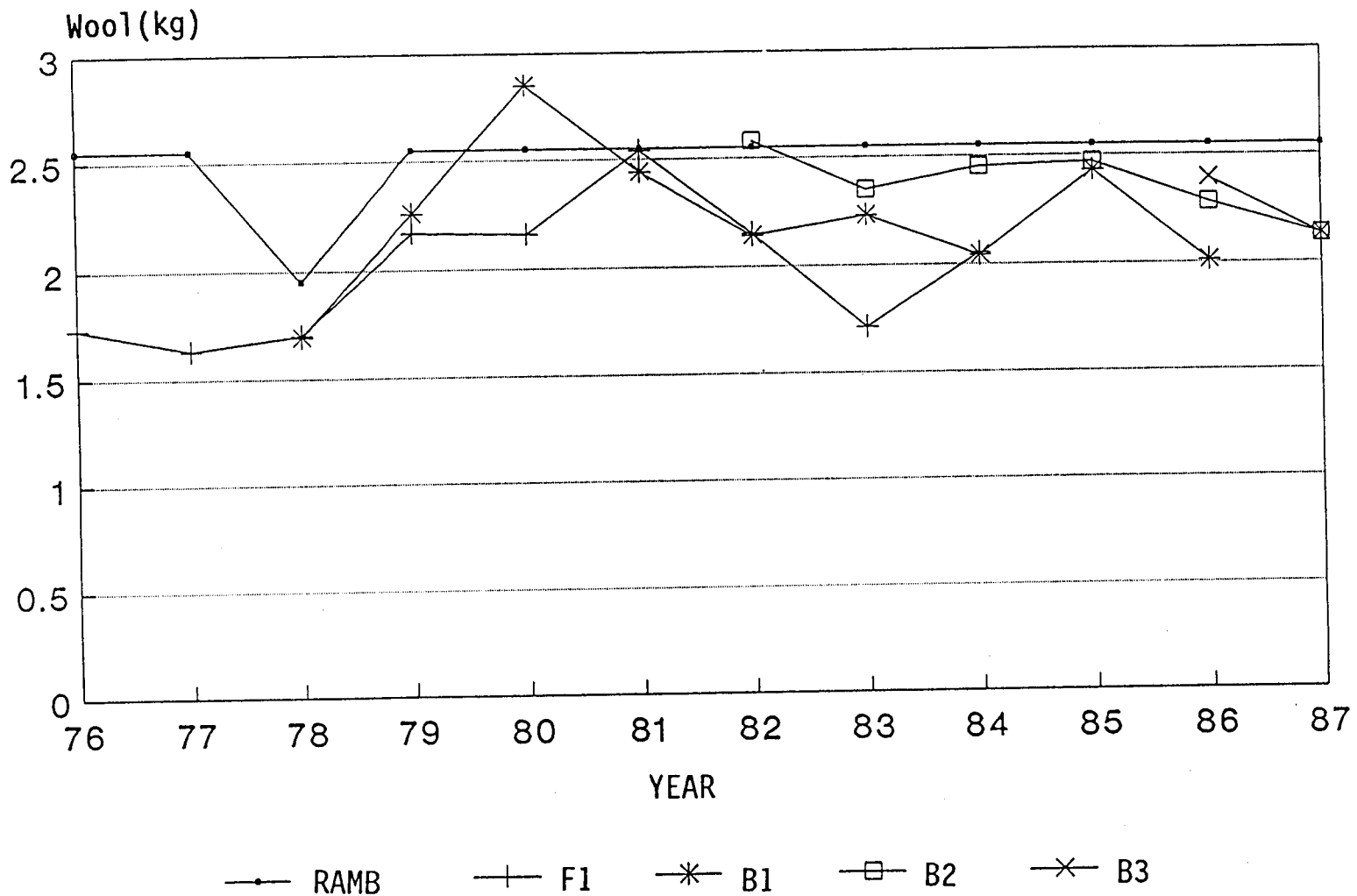


Figure 2 EWE WOOL PRODUCTION OF VARIOUS GENOTYPES



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